MEN WHO FOUND OUT

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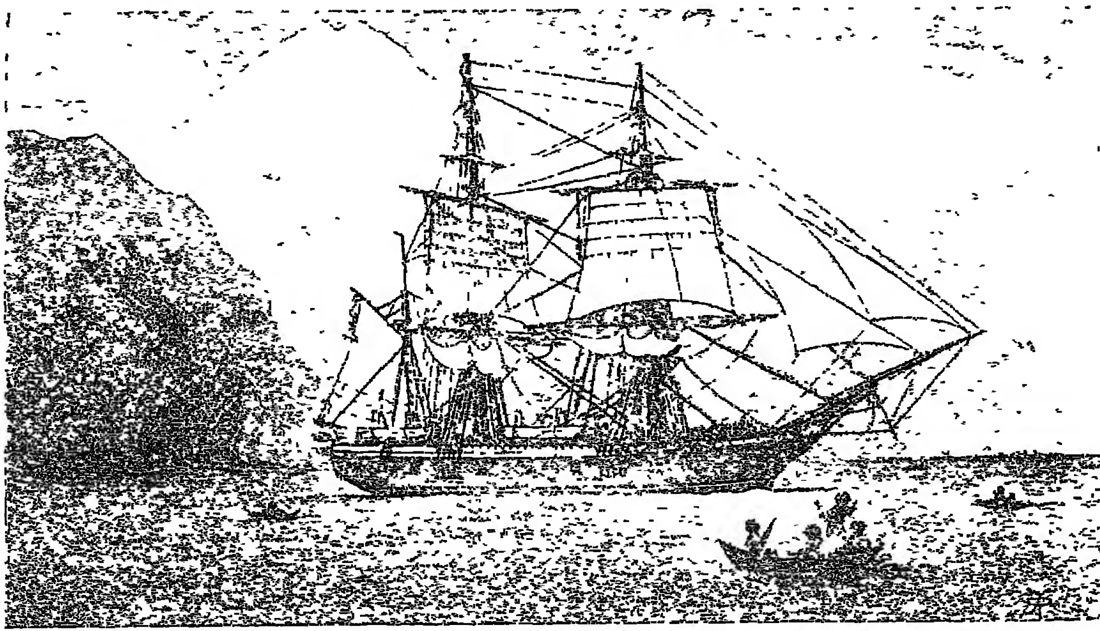

THE 'BEAGLE' *See the Story of Charles Darwin*

MEN WHO FOUND OUT

STORIES OF GREAT SCIENTIFIC DISCOVERERS

Amabel Williams-Ellis

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FOREWORD

These brief biographies of scientists are intended for boys and girls from about nine to fourteen. Some general notions run through them and these are given (overtly or covertly) in the first and last chapters and are illustrated by the sayings on page eleven. I have tried, for instance, to suggest that the impressive achievements of science, by means of which man has conquered nature (or could now conquer it) were arrived at by means which are not really remote from our everyday, practical, ways of thinking and of setting about our affairs, but that they are, however, methods that demand more careful and candid observation and more rigorous proof than we commonly bother about.

Looking at these scientists we notice that they were one and all intensely curious and very imaginative, and that they put two and two together pretty boldly, but then, when they had, were as cautious about testing their evidence as if they had been so many lawyers and detectives. Seeing them so inquisitive, so imaginative, seeing them going about their work, sometimes failing, sometimes succeeding, boys and girls may perhaps come to the conclusion that their way was a good way, their sort of imagination a fruitful kind, their sort of fame worth seeking, and their battles with the world better worth fighting than those of a good many of the great men of the school histories or of those (now even more famous) heroes of the Western, the Thriller and the weekly Comic. Unless we see it in the building, the great edifice of scientific achievement may well seem aloof, formidable and even incomprehensible. Alas, too, our moral sense may well revolt from some of the uses to which our knowledge of the natural sciences have been put.

These are not new problems. Perhaps as we see science in the making, and as the work of real people who also had moral problems to face, who were using common-sense methods, and who were criticised, helped and hindered by their families and their neighbours, the whole achievement (this immense, indeed predominant factor in our world)—appears in more manageable perspective Boys and girls are discovering the world for themselves , here are a handful of people who used some particularly fruitful methods of doing so

This little book had already been approved by a great many children, some of whom, both in Britain and overseas will have heard these true tales in broadcast versions The thanks of those who have enjoyed them are in large part due to the following :

Sir Walter Fletcher, Sir Charles Singer, Mr. Clifford Dobell, Mr. T P. Scott, Miss Mary Somerville, Professor Patrick Blackett, the late Dr. Maurice Newfield, the Secretaries and Librarians of The Royal Society, the Science Museum and the Royal Institution, and, not least, to the author's children

August 1957

Amabel Williams—Ellis

SAYINGS

'A fool is a man who never tried an experiment in his life.' ERASMUS DARWIN (grandfather of Charles Darwin)

'To be astonished at anything is the first movement of the mind towards discovery.' PASTEUR

'In the field of observation, chance only favours the mind which is prepared.' PASTEUR

'You ask me, What use is this discovery? I ask you, What use is a new-born child?' FRANKLIN

'Facts wait not on opinions. The things of nature bow not to antiquity. There is nothing more ancient or of higher honour than nature.' HARVEY

'Man comes into the world naked and unarmed, as if nature had destined him for a social creature, and ordained that he should live under equitable laws and in peace, and as if she had desired that he should be guided by reason rather than driven by force.' HARVEY

'I think that in discussing what we see and hear about the world of nature, we ought not to begin with texts from the Bible, but with experiment and demonstration, for from the Divine Word Scripture and Nature alike proceed.' GALILEO

MEN WHO FOUND OUT

STORY I

SOME GREEKS AND ROMANS

CHAPTER I

ONCE, LONG AGO, there lived a people on the earth who were beautiful to look at, who built beautifully, and who were not afraid to look about them. These were the Greeks.

They lived in white cities on the sides of mountains that sloped down to the Mediterranean Sea. It was a very blue sea, and the mountains in the distance looked mauve. Deep valleys, full of cypress trees and myrtle thickets where nightingales sang, ran between the mountains. The climate was warm, and people could live mostly out of doors. They had honey, and goat's milk, and olives, and wine.

There wasn't just one nation of Greeks, but several nations, and each of them had a separate city. Unfortunately the cities sometimes made war on each other. Then they fought on land

among the mountains, or at sea in wooden ships. But it happened that for a very long time these wars were not really very fierce, so that a peaceful life could go on in the cities between times.

It became the fashion in Greece to care very much whether the things you believed were true or not. In the time before the Greeks, and for a long while after, people either very much wanted to be rich, or else were frightened of all sorts of things. For instance, the Babylonians and Persians were rich, and also frightened of their gods, and of their kings, so that they were afraid to say anything that might offend them. They thought the gods might not like it if they asked too many questions about why lightning came, or why the tides rose, or what brought the rain or the locusts that ate up their crops. As for the kings, they often pretended to be half gods themselves. As this was nice for them but not true, they naturally did not like too many questions being asked about anything.

The Egyptians and also the Sumerians and Babylonians who lived in Mesopotamia had been very rich, for, in each of these countries, great rivers watered splendid corn lands.

Powerful kings ruled, and the king's officials—his scribes—had to be good at sums. They were expected to know if the barns would be big enough

for storing next year's corn, and how many beer, oil, and wine jars would be wanted. Great store-houses of stone and brick were built and also huge palaces and temples, and the scribes were expected to plan the amount of building materials needed, and to be able to say how many loaves of bread and jars of beer would be wanted for the army of builders who might be on such jobs for months and years. Also, because it was the floods from the great rivers that watered the corn fields each year, the scribes had to know about measuring land, for the floods not only watered the fields but often carried away boundary marks. So the Egyptians and the 'dwellers in Mesopotamia' gradually became good at arithmetic, geometry, and other kinds of mathematics. Later, the Greeks learned what these other people had found out. But, not having all that corn and wine to measure, not having to calculate when floods could be expected, the Greeks mostly used mathematics for finding out more about the things that we now call science.

They wanted to know why water ran down off the mountains, about fish and animals and men's and women's bodies, and how they worked. They even wanted to know *why* they wanted to know why. In the Greek cities there were all kinds of learned men, asking themselves and each other all sorts of questions about the world and the reasons

of things: and there were artists and singers and poets and architects, who lived and died, and worked quietly.

For instance, there was Aristotle, who lived in Athens, and who asked very much the sort of questions that we ask now. He asked why there were little bluish-purple branching streaks on people's arms, and he noticed that the blood flowed in a different way, in those purplish veins that lay near the surface, from the way in which it flowed in some deeper tubes—tubes that seemed to be alive, for they moved and fluttered under your finger. He cut up the brains and hearts of dead animals, not, as the Egyptians or the Babylonians would have done, to tell whether he was going to have good luck about buying a house or in a battle, but to see, if he could, how the brains and hearts were made. He cut eggs in half when they were half hatched, and he noticed that the chicken's heart developed first.

Aristotle experimented with moving things too. For instance he said that if you dropped two weights, one say of one pound, and one of ten pounds, then the ten-pound weight would fall ten times as fast as the one-pound weight. We shall hear more of this.

Then there was Euclid, who discovered a great deal about geometry and spaces—say, how to tell what size a three-sided field would be if you knew

how long two of the sides were, and how sharp the corner was where the lines met.

Plato was another Greek of whom we shall hear again. He was Aristotle's teacher.

Then there was Hippocrates, who was a doctor. Hippocrates was wise and kind. Before the days of the Greeks, doctors (except a few in Egypt) were generally just magicians. If you were ill they looked for, say, a bit of crocodile's liver, chopped it up, dried it, put it in a little bag, and hung it round your neck with a few prayers and something written about where the planets were when you were born. They then made you pay them a lot of gold, and said it was all their doing if you got better, and your own fault if you died.

But Hippocrates was like a modern doctor. If a man came in with a wounded head, Hippocrates would see if perhaps there were bits of bone broken off that were pressing on to his brain. He noticed that old people, if they were ill, could go without food for quite a long time without its doing them any harm; but that young people and children soon got ill and worn out if they did not eat. Also, that if you gave the same food to a person in a fever and to a person who was well, the person who was ill was simply made worse by what would do the healthy man good.

Hippocrates would have nothing to do with charms and mutterings. If he looked at a calf's

liver it was to try to see how calves' livers worked. The pretended magicians only looked as we look (for fun) at tea leaves or cherry stones, to see what luck we are going to have, whom we shall marry, and whether we are going to meet a stranger.

There was a great deal that Hippocrates did not know. He had not got a microscope, or even a watch to count people's pulses by; but both Hippocrates and Aristotle, and all the great Greeks, at any rate set about learning things in the right way.

Suppose you want to learn something about a particular plant. First, you should listen to everything that teachers and books can tell you about this plant; ask them who its cousins are, in what soil and what climate it is supposed to grow, what time of year it flowers, what you can use the juice for, and so on and so forth. But when you have done this you have not done the most important part. The most important part is to go and look at the plant for yourself; for it is quite likely that some of the things you have been told, and even things that are written in books, are not true. For even the best books and wisest teachers make some mistakes; and in learning you should, as far as you can, find out by trying.

There is a story told about this. King Charles the Second of England lived in a time when there were a great many people who called themselves

learned, but who never went and looked at things. If they were supposed to learn about a thing, they only read the Greek and Latin books about it —very often what Aristotle, whom we were talking about, or Euclid, or Hippocrates, had to say about it. But some of the younger men thought it best to read what Aristotle had to say, and then go and try for themselves (as well as they could) whether Aristotle was right or not. This, as you know, is often called making experiments.*

Charles the Second liked the experimenters and didn't like the snuffy old men with their noses in books, who never looked for themselves. So one day—the story goes—he said to the old men: 'Tell me why it is, that if you have a glass brim-full of water, and you slip in two little fish, it doesn't make the water overflow?'

The old men read and read, and thought and thought. They gave the King this reason and that reason. They said it was because the fish drank the water, they said it was because the fish were so slippery, they said all kinds of things.

But do you know the real answer?

I'm not going to tell it, but I will tell this much—that two little smooth pebbles or two little fish-shaped bits of plasticine will do just as well as real fish, if you do not live near a pond or near the

* Aristotle himself, of course, would have been on the side of the young men who tried for themselves.

sea. Try the experiment for yourself, and you will see what made Charles the Second laugh. Also you will know why the wise men were so angry with him when at last, in front of them all, he did what they had never thought of doing—tried the experiment.

CHAPTER 2

Perhaps you have read that after the Greeks came the Romans. The Romans were very good at military things and building roads and making laws, and sailing across the sea, but they were too busy to care, as much as the Greeks did, about finding out what the world was like. They had one excellent doctor called Galen, who mostly copied what Aristotle and Hippocrates had said, but who did find out quite a lot of things, because he was always working, trying to cure sick or wounded Roman soldiers. He was also the Emperor Marcus Aurelius's doctor. This Emperor was a learned man and I expect they had a great many interesting conversations. Of course there were other scientists too, but not much was found out in the time of the Romans. But then, later, after Galen was dead, there came the Barbarians out of the North and the Barbarians out of the East. In the end the Norsemen and Attila

and the Huns swept over the whole of Europe. They were savages—sea savages or land savages: they dressed in furs, and they could not read or write, and they thought of nothing but war, fighting, and pillage. They used to go to a city and burn all the houses down, kill all the men, or torture them to death, carry off the women and children as slaves, and sometimes they tortured them too. They didn't care a bit about finding out about anything, and never stopped to ask questions. They never seemed to want to know what made the colours in the rainbow, or what the noise of thunder was, or what made the blood spurt out of a man's body in a high fountain if you stuck your sword into him in certain places. They didn't care why streams flowed, or what made eels slippery, or what the stars were, or why the sun rose and set.

I suppose the Norsemen's and the Huns' children must have asked questions. I have often wondered how such people put their children off. The priests used to say that things were as they were, because there were gods, Hertha and Odin, Freya and Thor, who willed it so. The priests found out that by telling the people that this, that, or the other was displeasing to the gods, they could make the warriors do as they told them. They used to make them sacrifice cattle to the gods. Then the priests ate the flesh of the cattle

which had been sacrificed. Sometimes the priests would make the warriors sacrifice prisoners, beautiful maidens and so on. The chief point was that the priests answered all the questions—not by trying to find out what was true, but by thinking how they could best get these fierce fighting men into their power and make them do as they chose.

This sort of thing went on for hundreds and hundreds of years. The priests were powerful: it was very dangerous to ask the real reason why, about anything that happened, because they could always say that you were displeasing the gods by asking questions, and that if you asked so much, then there would be a drought or a flood or a thunderstorm, or the chief's armies would be beaten in battle, because the gods would be angry. The priests never wanted people to find out the truth, because that would have spoilt their power.

Jesus once said: 'The truth shall make you free'; but even after Christianity came, the Christian priests and the Christian churches, both Catholic and Protestant, often went on forbidding people to find out the truth about their own bodies, or other animals, or the stars. In several of the stories of great discoverers in this book you will find that. Several times you will read that there were priests or religious people—very often Christians—who did not seem to

believe that what Jesus said was true, that the truth will make you free: or perhaps they did not think it was good for people to be free. As you will see, it has often been dangerous for a man to find out the truth.

To this day there are certain kinds of knowledge which it is by no means safe to look for, and certain things that it is not at all 'healthy' to say even if you think that they are true. If you go out after this sort of knowledge you will not, as a rule, run the risks that Galileo ran, though I do myself know a number of people, both men and women, who have been imprisoned and even tortured because of true things they believed and said.

What happens more often nowadays in England or America, is that people who believe what is not generally believed, or who insist on thinking out things for themselves, find it hard to make a living. The more old-fashioned people are generally the people who decide who is to get the best jobs. They often, honestly, think that people who think too much for themselves are wicked. Certainly it would not be right to give a wicked man a job, instead of giving it to a good man.

When you hear older people declaring that someone is a wicked Communist or a wicked Atheist, or a wicked psychiatrist, remember that it may be true. These people may be wicked. People who have new ideas are not always nice,

and some new ideas are extremely silly. But do also read the story of Galileo, and remember what people thought about Harvey and Darwin at first.

STORY II

GALILEO GALILEI
(1564–1642)

CHAPTER I

IN THE YEAR 1564, when Elizabeth was Queen in England, and when men wore ruffs and ear-rings, and women wore hoops to hold out their stiff skirts, a little boy was born in Florence in Italy. They christened him Galileo. His father and mother were rather poor, and they had a good many children. But Galileo's father was one of the people who like to find out: he did not think much of just agreeing with what other people had said.

Galileo, his boy, was very clever with his fingers: he used to make toys that had wheels and pulleys and strings. Some of them worked, but most of them didn't.

When he was about twelve or fourteen his father taught him the lute,* and he became a very good

* A lute is rather like a guitar, and a little like a ukelele, only bigger.

player with a very delicate touch. He played the organ, too, but the lute was his favourite, and he could play it with his eyes shut. He would sit for hours on the marble steps of some palace, his knees crossed, his head bent over his lute, his long hair falling into his eyes. This boy could draw and paint too, and loved bright colours, gold, and lapis, and rose colour. Florence was full of famous painters. Galileo could draw a church tower at the end of the street, or the top of a table with fruit and plates on it, so that the street and the table looked level, and so that the things looked the right distance from one another.

When he was about sixteen, he used to be a nuisance to his teachers. When they told him what Plato said about something, he said : 'Yes, but did Plato really know? Had he tried?' And when they said: 'But Aristotle says so, too,' he said : 'But wasn't Aristotle copying Plato, perhaps?' They thought that to be a learned man all you needed was to know by heart what Aristotle had said. To understand him was only just necessary, or perhaps not necessary, and to contradict him was wicked. But this boy Galileo very often dared to contradict.

Galileo made his first invention when he was about eighteen. One afternoon he was saying his prayers in the cathedral at Pisa. The cathedral was very high—so high you could scarcely see

the roof in the dim light; and from the very highest part of the middle dome, on an immense chain, there hung a beautiful bronze lamp.

As Galileo knelt there, the choir-boy whose work it was to light the lamp came with his burning taper and pulled the lamp towards him as it hung on its chain. When it was lit, the boy let it swing back again.

Galileo began to watch. At first the lamp with its lights swung a long way backwards and forwards, casting queer shadows; then the swing began to 'die' and it began to go much less far.

It was odd, and yet it seemed to Galileo that the lamp took nearly as long to swing the shorter distance as it had taken to swing the long distance when the choir-boy first let go of it. He wanted to make sure. He had no watch, but he put his finger on his pulse and counted it by that. Great was his surprise when he found that when the lamp was nearly quiet, it took it just as long to do its little short swing as it had taken it to do the long swing.

This was a new discovery. The length of time it takes a pendulum to swing depends not on the distance it swings, but only on the length of the chain or string.

Galileo thought of a way in which he could use his knowledge. Doctors, as you know, often have to see how quick or slow people's pulses are;

but most doctors, even in Italy, had not got any watches in those days, so they could not tell exactly how fast the pulse beat.

So Galileo thought of the idea of using a little pendulum (which is simply a weight swinging on a thread); for he saw that if the pendulum always swung at the same pace, then they could count a sick person's pulse by that—a long string would measure a slow pulse, a short string would measure a quick one. So he went home, and soon had ready a little instrument, which delighted the doctors in Florence. At the end of the story you will find a description of how to arrange a pendulum. Here I will not interrupt the story any more except to say that unless Galileo or somebody else had made this discovery, the grandfather clock and the cuckoo clock and many other kinds of clock would not be possible. They depend on this curious behaviour of the pendulum, the first of all Galileo's discoveries.

Galileo's father wanted his son to be a doctor, and he was rather afraid that that was just what he was not going to be. He was afraid that Galileo wanted to be a mathematician or an astronomer. But nobody thought anything of *them*. For instance, at the University of Pisa the Professor of Medicine (the man who taught young doctors) got 2000 scudi, or about £433 a year, while the Professor of Mathematics only got 60 scudi, or £13.

Galileo's father scolded him, and told him how poor he would be if he *would* learn mathematics. However, Galileo was almost grown up, so it was no good, and at last he had to be allowed to learn what he wanted.

He was still a very tiresome scholar, and they soon called him 'The Wrangler,' because he would wrangle and argue with the teachers.

When he was twenty-six, Galileo was made Professor of Mathematics. Just as his father had warned him, he was only paid £39 a year, or 15 shillings a week. But though he had to help his father and mother and sisters by giving lessons in his spare time, Galileo never regretted having learned the things he wanted to know. But the other professors at Pisa regretted it, for Galileo was always making trouble and refusing to believe what was in the books.

For instance, you remember that Aristotle had said (and these professors had always taught) that if you drop two weights, say a one-pound weight and a ten-pound weight, the ten-pound weight will fall ten times faster than the one-pound weight, because it is ten times heavier. This sounded sensible and true. But now this tiresome young man came along and said it was all nonsense, and that the weights did nothing of the kind. The old professors looked over their spectacles at him, and pointed to the books and said: 'You're wrong,

young Galileo. Look—here it is, quite plainly written down. Can't you read? Aristotle says so distinctly.'

'But,' said Galileo, 'the weights don't say so. I'll show you.'

So one morning, when it was fine, he got all the professors and students to come out of the class-rooms down into the big square where the famous Leaning Tower of Pisa stands. Then, while they all waited in the sunshine, Galileo ran up the stairs to the very top of the tower, where he had got ready two cannon-balls, one—a little one—weighing one pound, the other—a big one—weighing a hundred pounds. He balanced them carefully on the edge of the tower, and while everyone held their breath to see what would happen, he let them both drop. They struck the ground together. Aristotle had been wrong.

You may think that the professors with long grey beards and their noses in books, always believed Galileo after that. They had seen with their eyes, they had heard with their ears. It had all been in daylight on a fine morning. But they went back muttering and discontented to their books. They went back to invent reasons why the weights had behaved in that way just this once.

The fact was, they did not want to believe. As things were, everybody looked up to them and

thought them very clever and very wonderful. But really the only thing they knew how to do was how to read Latin and Greek books. There were probably plenty of people who knew far more than they did about dropping cannon-balls off towers and trying other experiments. They were thoroughly selfish, so, as you can see, it would never do for them to admit that the right way to find out about things was to go and try. But this was just what Galileo did; he found out about what things would float and what would not, and about how far a ball would roll down one hill and up the next. Almost all these experiments were about moving things which no one had bothered about much.

That was one lot of people offended. But Galileo soon managed to offend someone else. There was a Prince, Giovanni de' Medici, who had invented a machine for cleaning out harbours that had silted up. A small model of it was made. The Grand Duke asked Galileo's opinion. He looked at it, and said it would not work. The Prince who had invented it was bitterly offended and angry; and it was not long before Galileo began to be hissed at his lectures. Soon the Prince and the snuffy old professors made Pisa so unpleasant for Galileo that he had to go away.*

* Galileo was right about the machine They built it full-size, and it cost a lot of money, and was no use at all.

Galileo soon got another job in a city called Padua; and it was a good thing he did, for by now his parents were dead, and he had a younger brother and three sisters to keep.

CHAPTER 2

Now nearly everybody at this time, 1598,* still believed that the sun went round the earth. They thought this stood to reason, first, because the ground feels firm, and secondly, because the earth was the most important thing in the universe. Some people believed then that the earth was a sort of flat island, floating in an enormous sea, and that the sun went round it, dipping under the sea. Some people thought it might be round, but somehow held firm. The moon was simply meant to be useful. As for the stars, people said they were either ornaments or a kind of magic. For instance, they believed that when a child was born, a new star—the child's guiding star—came into the sky; and if you could only discover which that star was, you could find out all about what was going to happen to the child. A great many cheating professors made a good living by pretending they understood all this. They were

* Elizabeth was still Queen of England; it was after the Armada, and Shakespeare was writing plays.

astrologers, and what they did was called casting a horoscope.

But some time before the days of Galileo, there had lived a monk called Copernicus. He had no telescope, but for many years he watched the heavens, turning night into day. The stars and planets, as you know, are seen at different parts of the sky at different times, and Copernicus wanted to understand how they moved. At last, after watching for a long time how the planets wheeled about the sky, he came to the conclusion that it was the sun that was the centre of all this movement, and not the earth at all. The rising and setting of the sun, Copernicus believed, was not made by the sun's movements, but by the spinning of the earth. The earth, he said, is a planet, just like Venus, or Jupiter, or Mars, and it spins like a top for day and night, and also revolves round the sun for the year.

This seemed to most people the most ridiculous idea that was ever thought of. Think, they said, of the solid earth, with trees, houses, cities, mountains, seas, and continents—Asia, Africa, and America—spinning like a top, all day and all night, and besides that, rushing round the sun every year.* It wasn't only impossible to believe—it was a most shocking idea, they said. If the earth was not the chief and middle of the universe, if the sun and the

* Actually, it spins at the rate of nineteen miles a second.

planets and stars were not attendant lights at all, but splendid worlds, larger and more important than ours, then what about man? Perhaps each new child was not important enough to have a star of its own, perhaps even kings were not very important, perhaps (they only whispered this in Italy) even the Pope himself was not very important? Both the very religious people and the Aristotelians* were shocked, though the Pope of that day was interested and sensible.

As you can imagine, this idea of Copernicus was just the sort of uncomfortable thing that Galileo would be sure to believe. While he was quite a young man he already called himself a Copernican.† But this was a thing that he only told his intimate friends, especially a great astronomer named Kepler, to whom he used to write letters. The difficulty was, of course, to prove anything that went so clear against what you felt and seemed to see.

And now an interesting thing happened. In a little Dutch town called Middelburg there lived a spectacle maker. One day one of the shop-boys was playing about with some spectacle glasses, holding them at different distances from his eye. Suddenly he saw that if he looked through two of them, fixed apart, he could see the weather-cock

* People who believed what Aristotle had written.
† A person who believed what Copernicus taught

on the Middelburg church spire much nearer and upside-down.

This toy was bought by a nobleman. The nobleman showed it to a general The general used it for finding out the movements of the enemy. Soon a lot of people began to talk about this glass by which you could see things much nearer and upside-down. Galileo was famous by this time and had a lot of friends, so it was not long before he heard the gossip about the new toy. All that night he sat up thinking. He knew a good deal about spectacle lenses and magnifying glasses, and he wondered if he could make a glass too, not for seeing church spires and the enemy's out-posts, but to spy upon the moon and stars.

He thought of about six different ways in which perhaps the glass might have been made. When the daylight came he started trying each of these ways, one after the other. At last he tried this: he took a small old organ-pipe, jammed a bulgy spectacle glass into one end, and a hollow spectacle glass into the other end (next his eye), and looked through it. It made things look three times as near and not upside-down. He had made the first telescope in the world !*

Everybody was excited. All sorts of stories began to fly about. News reached Venice that

* Opera glasses are made like that to this day, but for telescopes a better way has been found

Galileo, the professor at Padua, had made a wonderful spy-glass. The Doge* and all the grandees wanted to see it, and sent for Galileo at once. The excitement was tremendous. Galileo wrote a long letter to his brother-in-law, describing what happened:

'Many of the nobles and senators, although of a great age, mounted more than once to the top of the highest church tower in Venice, in order to see sails and shipping that were so far off that it was two hours before they could be seen without my spy-glass. We could see them steering full sail into the harbour. . . . Seeing that His Serenity the Doge desired to possess it, I resolved to go to the Palace and present it as a free gift.'

The Doge was delighted, and appointed Galileo to be Professor for life.

Galileo soon made himself a very much better telescope than the one he had given to the Doge. He ground the lenses with his own hands and set them in the long tube Now he was ready to go out exploring the sky, and see things that no living man had yet seen.

The first thing he thought he would look at was the moon. People in those days were sure that the moon was an exquisite, smooth, silver

* He was the head of the Venetian Republic, old and powerful, and wore scarlet and ermine robes and a high white cap sewn with pearls

globe, a polished mirror for the sun's light. Galileo did not feel so sure.

Then for the first time a man on the earth saw and knew for certain that the moon is a small, queer world, rather like the earth, with mountains and valleys, volcano craters like the ones in Sicily, plains like the ones in Lombardy, and perhaps seas like the Adriatic Sea, which washed the walls of the Venetian palaces. He looked and looked.

The other professors were furious when he told them what he had seen. They said he had spoilt the moon. She was pure and smooth, like a piece of crystal He was hateful to say she was only made of earth. One professor entirely refused to believe that there could be mountains on the moon. He said it was impossible, and explained why. He said that on the earth, mountains and seas had been made for the benefit of the plants and animals, and the plants and animals had been made for the benefit of man. But everybody knew that there were no men on the moon, therefore there could be no plants and animals on the moon, therefore there could be no mountains and seas on the moon. He looked very triumphantly at Galileo when he had said this. Galileo only asked him to look through the telescope.

Galileo calculated from what he saw through his small telescope that many of the mountains on

the moon must be about five miles high, or some even as much as seven (higher than Everest). Although nowadays astronomers have telescopes a thousand times as good as Galileo's, they quite agree with him about the height of the moon's mountains.

I don't expect that Galileo spent very many nights in bed after he had made his second telescope. Everywhere he looked he saw something that nobody had ever seen before. He thought he knew every star in the sky, but now wherever he turned his glass new stars appeared. For instance, people had wondered for a long time what the Milky Way could be. Galileo's telescope showed that it was all made up of stars. There were odd-looking double stars to be seen, too, and many new sights.

It was on a cold night in January, 1610, that Galileo noticed something that led to another discovery. He was looking at the planet Jupiter, and he noticed that that evening it had three very small stars near it, one on one side, two on the other. This he noted down in his notebook. The next night he looked through his telescope again. Now all the three stars were on the right side of Jupiter. The next night was cloudy, and he could see nothing. On the next it was clear again: there were only two small stars near Jupiter, and these were on the left-hand side.

The next night there were two small stars again, but one was bigger than the other. He could not make it out : the little stars round Jupiter seemed to be dancing.

Then Galileo realized what the explanation was. Jupiter had moons—not one like the earth, but several.

The news of this discovery soon spread, and excited the greatest interest and astonishment among astronomers all over Europe. As you will have guessed, the old professors and the people who wouldn't believe in Copernicus wouldn't believe this. Galileo as usual invited them to look through his telescope : some looked, but these had already thought of an excuse. They said that this new telescope acted well enough for things on the earth, but it was no good for things such a long way off as the stars : it showed things all wrong, they said.

Others wouldn't look down the telescope at all. One of the professors who wouldn't look happened to die soon after he had refused. Galileo said he hoped he would perhaps see Jupiter's moons when he was on his way up to heaven.

But people were not all stupid. Some of the greatest astronomers, his friend Kepler for instance, were delighted. An astronomer named Wachenfels took a posting carriage as soon as he heard that Jupiter had moons, and went off to

tell Kepler. At the end of his journey he rushed into Kepler's house all out of breath, and told him before he even took off his hat and coat Kepler was so excited he didn't know what to do. He wrote about it to Galileo :

' Such a fit of wonder seized me. . . . I was thrown into such agitation . . . that between his joy, my colouring, and the laughter of us both, confounded as we were by such a novelty, we were hardly capable, he of speaking or I of listening . . . I long for a telescope to anticipate you if possible in discovering two moons round Mars, six or eight round Saturn, and one each round Mercury and Venus.'

But Kepler's being sensible didn't stop some of the others from being silly. This is what one of the Aristotelian professors wrote :

' Jupiter's moons are invisible to the naked eye, and therefore can have no influence on the earth, and therefore would be useless, and therefore do not exist.'

Galileo answered that, however good this argument might be, it was not good enough to destroy the moons, when they had actually been seen.

Galileo wrote to Kepler :

' Oh, my dear Kepler, how I wish we could have one hearty laugh together ! Here at Padua is the principal professor of philosophy, whom I have repeatedly and urgently requested to look at the

moon and planets through my glass, which he persistently refuses to do. Why are you not here? What shouts of laughter we should have at this glorious folly, and to hear the professor of philosophy at Padua labouring before the Grand Duke with logical arguments as if they were magical incantations and could charm the new moons out of the sky!'

Now I must break off the story to tell about something that had happened which might have given Galileo an uncomfortable feeling.

In Venice there had lived, when Galileo was a student, a man called Bruno. He had many unusual opinions about a lot of things, and especially he was a Copernican—that is to say, he believed, just as Galileo did, that it is the earth that moves round the sun.

The Inquisition in Rome sent for Bruno. They wanted to try him for heresy.* They kept him in a dungeon in Rome for six years, and then,

* Heresy meant still believing something which the Pope and the Inquisition had said was wicked The Inquisition was a set of very learned archbishops, bishops, and priests At first it was their work to say what you might and might not believe There were one or two Inquisitors in each city in Italy, Spain, Belgium, and so on But gradually the Inquisitors became more like judges, who punished heretics, than learned bishops who helped people to know what they ought to believe By Bruno's and Galileo's time the Inquisition often behaved cruelly, as you will see They behaved as they did because they thought that it was very necessary, if a person was to have any chance of getting to heaven, to hold exactly correct beliefs They thought the new ideas were bound to make people cease to believe correctly, so they were terrified lest the new ideas should spread,

as he refused to say that he didn't believe the things he did believe, he was burnt alive.

Some of the priests and bishops and abbots tried to protect Bruno and, later, Galileo; but some of the others, and particularly the people who belonged to the Inquisition, were quite ready to tell him what he was to believe, and punish him if he disobeyed.

So now Galileo's enemies took their stand on the Bible, and muttered that it was impossible to believe both Galileo's new discoveries *and* the Bible.

Now the fact was that Galileo himself believed in the Bible, and was a religious man.

'I am inclined to think,' he wrote, 'that the Bible is meant to make men understand those truths which are needed for their salvation. . . . But I am not bound to believe that the same God who has endowed us with senses, reason, and understanding, does not permit us to use them, and desires to acquaint us in another way with such knowledge as we are in a position to find out for ourselves. Especially I do not believe it concerning those sciences about which the Bible contains only small fragments and several different explanations. There is so little about astronomy, for instance, that the planets are not all spoken of. I think that in discussing what we see and hear about the world of nature, we ought not to begin with texts from the Bible, but with experiment and demonstration, for from the Divine Word Scripture and Nature alike proceed.'

Now there began to be a real row. Some of the churchmen in Rome argued that Galileo was a religious man, and that you could believe all that he taught and still be religious. Some of them said—Not at all.

The chief and greatest Inquisition, the one in Rome, held a solemn enquiry. Galileo felt sure that if the churchmen at Rome who had to decide could only hear how reasonable he was, they would all believe in him ; so when the Pope ordered him to come and explain, he gladly went to Rome.

For the time being Galileo was very well received. He showed the Cardinals his telescope, and, to as many as would look through it, he showed Jupiter's moons. He talked and made speeches by the hour, and felt sure that he had made everybody believe him, and that the Church would soon allow people quite openly to say that they believed that it was the earth and not the sun that moved.

Just as he felt sure that everything was settled, the Inquisition summoned Galileo before them and said that he must give up this idea. They were not astronomers, yet they told the greatest living astronomer that from now on he must believe that the sun goes round the earth, that the earth stands still and is the centre of the universe. They ordered him never even to discuss his discoveries again. If he did not agree to all this, they

said, they would stop his work altogether, for he would be shut up in prison.

Galileo could do nothing but promise to obey. He went home, miserable. He wanted to go on with his discoveries, he wanted to hear what other people were discovering, he wanted to encourage other people, to get telescopes to find out more things Sun spots, for instance. He had discovered that on the bright disc of the sun there were spots. Were these mountains, like the spots on the moon, or what were they? But now it would be almost impossible to work. The only way he could speak about what he believed, was to treat the whole thing as a kind of fairy-tale, and begin everything with 'If' or 'Suppose'—'If the earth went round the sun,' he would have to say, and he would have to treat it as a story and a dream. Even then the Inquisition might object He tried to work at other things; but he was very miserable, and now he was often very ill.

CHAPTER 3

By this time Galileo was fifty-three. None of his family seem to have been very fond of him, except one very nice daughter, Maria Celeste She was a nun, and seems to have been a charming person. A great many of the letters she wrote to

him still exist. She was always mending his collars and cuffs, or sending him sweets and fresh eggs, or copying out papers for him. She was very good at making candied fruit, especially candied citrons. Sometimes she asks him for things—a coverlet for her bed, or some seeds for the convent garden. Sometimes she sends him 'six large cakes' or a box of small sweet biscuits. Now he took a villa near her convent, and, except when he was ill, he used to go and see her every day. It was lucky that there was this gentle Maria Celeste who really loved him. For he was terribly disappointed by the decision of the Inquisition. The worst of it, for him, was that he did not hate the Church. He always hoped that if the priests and bishops would only listen, and look through his telescope, they would soon admit that he knew best about astronomy, just as they knew best about Church matters.

Time went on, till at last he could bear it no longer. He thought that before he got quite old he would just risk writing one more book, a nice interesting one The book was in the form of a conversation, and both the idea that the earth moved, and the idea that it didn't, were set out in it. He did not mean to be quite fair to the idea that the earth didn't move, but all the same he hoped that like that he would please everybody. He was going (after a fashion, anyhow) to put the view that he

didn't believe, and he was not going to say that what he did believe was certainly true.

He wrote this new little book out several times, and sent it to a few of his best friends. The astronomers to whom he sent it said that it was excellent and ought certainly to be printed, so that all the other astronomers and students could get the benefit of all he had to teach. Galileo thought he would take the book to the Pope and see if he could not be allowed to print it. So he went off to Rome again, and let the Pope and the Inquisition have copies of the book, which was in the form of a conversation between three people.

There was a new Pope now—Urban the Eighth, clever, but vain. Sure enough, Galileo was very well received by him and they had many agreeable talks together, and everything seemed to be going well. The book was shown to the Pope and to people at the Inquisition, and they said that if he would alter this, that, and the other in it, he might certainly print it.

Galileo was quite willing to alter and alter it if only they would let him publish it.

This all took a long time. Galileo became very impatient: he was old and rather ill. He felt he might die before these people could make up their minds. However, at last, after the book had been altered and altered, permission was given to print it.

What a joy for Galileo! A whole lot of copies were printed. The book was in Italian, and amusingly and interestingly written, with jokes as well as serious astronomy. All the clever people in Europe were soon buying and reading it. Everybody said how good it was, and how clever Galileo was.

Then, when everything seemed all right, the blow fell. It is true that all the clever people and all Galileo's friends were delighted. All the more, therefore, were his enemies vexed. All this excitement and praise was unbearable to them. Those who hated freedom of thought, those who preferred to read musty books, those who would not look through telescopes for fear of seeing Jupiter's moons, those who did not believe that anything could exist unless they could see the use of it, all such enemies of Galileo were thoroughly alarmed at the pleasure that people were taking in the new book.

Suddenly the Pope and the Inquisition said it had all been a mistake: they told Galileo that they had never meant to give permission for the book to be published. How dared Galileo do such a thing, when years ago he had been ordered never again to discuss the idea that the earth moved! It was no use for him to say that they had themselves said he might. They did not care, but said he must come to Rome at once and be punished

for his wickedness. It was no use for him to say that he was ill and there was plague in some of the towns he had to pass through They did not care. He said he was old now and too ill to ride They did not care, and said he could be carried.

His kind daughter, the nun, Maria Celeste, was in despair. It was dreadful that Galileo, who had done so much and made everybody honour the name of Italy, should be treated like a criminal in his old age!

Now he had a very different reception in Rome from the one he had had before. He was ordered to keep indoors, and show himself as little as possible. At first he was allowed to stay at the house of a friendly Ambassador instead of in a prison. The Ambassador's wife was kind to him, and both of them honoured him. But he was very unhappy.

Soon he was removed to the prison of the Inquisition for several days. Here he was cross-questioned for hours at a time. He knew that the people who questioned him had power not only to execute him, but, far more terrible, to torture him. They sat, solemn and black, priests and bishops. He was in their power. What made things so bad for Galileo was that he could not feel that these churchmen ought to be his enemies. He believed in God just as they did. It was like being badly treated by his own friends.

With all this disappointment, anxiety, and sorrow, his health began to give way. He became so ill that they thought he might die, and presently he was allowed to go back to the Ambassador's house.

The Inquisition had decided that Galileo must be made to recant—to say publicly and solemnly that everything about stars in the Bible was true, that the earth stood firm and fixed, and was the centre of the universe, and that the sun and planets went round it.

Every time Galileo was sent for by the Inquisition, he was in danger of being tortured unless he recanted. All his friends begged him to give in: they said that resistance was hopeless and useless—they reminded him of the fate of Bruno.

Day after day the poor old man was had up before those solemn, terrible, ignorant judges One day in June, he was summoned again and told that he would be wanted all day for a 'rigorous examination.' That, as he very well knew, usually meant torture. Early next morning he was taken to the prison of the Inquisition, and he did not reappear until three days later.

What Galileo actually went through in those three days nobody knows. I don't think they actually tortured him. Some people are sorry that he did not hold out—that he did not let them rack him and burn him rather than give in.

But he didn't hold out. At one stage or another of the three days he said: 'I am in your hands—I will say whatever you wish.'

So the next day, dressed in a white sheet as a penitent, the venerable old man, who ought to have been honoured by everyone, whose only crime was that of being the best scientist of his age, was taken to a great room filled with seats, tier upon tier. Here the Cardinals, bishops, and priests of the Church were all sitting, magnificent and at their ease. Here Galileo had to kneel before these 'most eminent, most reverend, Lords, Cardinals, General Inquisitors of the Universal Christian Republic.' Here, shamefully kneeling, he had to say that he would never again teach the false opinion which maintains that the earth moves. He had to say that 'with a sincere heart and unfeigned faith he abjured, cursed, and detested the said errors and heresies.' He had to swear that he would never in future say or write in favour of this idea, and that he would even tell the Inquisitors if any pupil of his believed what he had formerly taught.

There is a story that as he rose from his knees he murmured to a friend: 'But it *does* move.' But I am afraid that that story is not true—Galileo had no friend in that dreadful place. He was a broken and disgraced old man.

You can imagine how pleased his enemies were.

Galileo himself had said that what he had taught was false! Far and wide spread the news of Galileo's recantation. Copies of what he had been made to say were sent to all the universities. The professors were ordered to read it to the students. At Florence, his home, it was read out in the cathedral, and the Inquisitors specially arranged that all his friends should be made to come and hear it.

Poor Maria Celeste was ill by this time. She was worn out with anxiety and saying prayers for her father's safety. It had been hard to get news at the convent, and she had felt the disgrace terribly. She did not think she would live much longer. Her one wish was to see her 'dearest lord and father' before she died. At the last moment the wish was granted, and once more father and daughter were together. Six days after her father came she died. Galileo was broken-hearted.

He asked for permission to go and live at his old home in Florence. He was met by the answer that he was to stay where he was, and not to go out of the house nor to receive visitors, and that if he asked for more favours he would be taken back to Rome and put into a real dungeon.

He had come to the time of his old age when he ought to have been most honoured and most renowned, and was instead disgraced and wretched

and ashamed. But even now he worked. He wrote a dialogue about motion, which is now reckoned one of his best works, and he even made one more astronomical discovery, about a curious swaying motion that the moon has.*

And now came the last blow. He became quite blind. He had seen more than any mortal man before him had seen; he had seen world beyond world, sights unimagined till he saw them. Now he could not see his own hand or the cuff that Maria Celeste had hemmed so delicately.

'Henceforth,' he said, 'this heaven, this universe, which by wonderful observations I had enlarged a hundred and a thousand times beyond the thought of former ages, has shrunk for me into the narrow space which I myself fill in it.'

But in one way this last trouble was not so bad, for the Inquisition, thinking he was thoroughly tamed and broken, allowed him to have a secretary. Three of his pupils managed to come and see him every day, and occasional visitors were even allowed, though they had to be talked to first by a sort of priest who was his gaoler. Many visitors came to see him like this, and one of them was the English poet, John Milton, who wrote *Paradise Lost* and worked for Oliver Cromwell.

The Inquisition was right, though, in thinking

* Called 'libration'

that Galileo was finished. He could not struggle for the truth any more ; the days were gone when he and Kepler could laugh together over the follies of the learned.

When he died his enemies wanted to refuse him burial—they would not allow his friends to put up a monument, and threatened to cart away his bones if they attempted to do so. And so they hoped that he and his work might be forgotten.

EXPERIMENTS

I

1 Make a pendulum This is done by tying a small weight to the end of a piece of thin string or thread. The weights may be small iron nuts, pieces of lead, or kitchen weights They can be hung from nails, or at the end of a stick or a ruler stuck out over the edge of a table or desk, but make sure that the support is absolutely firm.

Measure the string from the point from which the weight is hung to the middle of the weight. We shall call this the length of the pendulum

To start the pendulum swinging, hold it straight out and let go Do not push it. If possible, have a clock or watch ready that shows seconds as well as minutes If this is impossible, look at the minute hand very carefully.

2. Pull out the pendulum some way and count how many times it will swing in a minute.
3. Pull out the pendulum only a very little way, and see how many times it will swing in a minute
4 Make two or three pendulums of different weights but of exactly the same length, and see how many times each will swing in a minute.
5. Now make one of the pendulums only half as long and count the number of swings it will make in one minute.
6. See how long the string has to be for the pendulum to swing in time to (*a*) your pulse, (*b*) a grown-up's pulse, (*c*) the pulse of a boy or girl who has just run twice round the garden or ten houses down the street and back.

II

Ask a grown-up person to take two kitchen weights, one of 1 lb., and one of 4 or 5 lb., and (if he thinks it safe) drop them out of a second-floor window, or anyhow from a good high pair of steps. See if they drop together or not.

STORY III

WILLIAM HARVEY

(1578–1657)

CHAPTER I

IT WAS A FINE morning in London about ten years before Charles the First came to the throne. The London streets were not at all like the streets of a big town nowadays In the first place, they were very muddy. nobody had yet discovered a way of making a tarred road. Most people rode about their business, but some were drawn along in heavy coaches or were carried in litters. The everyday coaches were rather like the sort of State coach that the Queen or the Lord Mayor of London rides in now. Only, of course, they were often very shabby. The streets were narrow and the houses leaned towards each other in some places so that they nearly touched There were a lot of shabby people about, and there was a great deal of noise.

The noises were different from the noises nowadays. There were people going round from house

to house with things to sell, just, as in my young day, people went about selling lavender and fire-logs in London. One man was shouting 'Water to sell!' A woman was calling out 'Lily-white sand oh!' another 'Chairs to mend'; and a big brown gipsy-woman with a baby in her arms had a great basket of cherries. 'Fresh, full and fair ones!' she was crying, 'Come and buy!'

Then two footmen came running slowly with long staves in their hands, clearing the people away. Behind them came a coach. Just for a moment a lady looked out: her hair was scraped back off her face, and piled with jewels. She had long ear-rings, round her neck was a saffron-coloured ruff, and she held a white handkerchief to her delicate nose. It was quite true that the street was smelly.

After the coach came a lot of people walking, and then a man riding slowly: the horse was plump, and walked demurely. By the stirrup walked a man-servant in a rusty black gown: he looked quiet and grave. On the horse's back sat a little short man in a black velvet gown: his face was round, and he had round, very black eyes that glanced about him shrewdly. He looked as if he might have a temper. His hair was black. Although his eyes glanced about, he was not noticing very much what went on in the street, and took no notice of the woman with

cherries to sell. You could see he was thinking about something.

His name was William Harvey, and he was a famous doctor. Just now he was riding out to see Lord Chancellor Bacon, who was ill Harvey felt a little peevish about having to go and see Lord Chancellor Bacon. This lord gave himself great airs, and thought himself very wise and philosophical. Certainly he was a great man. But Harvey did not think much of him. Francis Bacon had never been trained as a doctor and he had never made an experiment in his life—he only wrote very beautifully about finding things out; but Harvey had his doubts of him.

Harvey was also thinking that he had got to give a set of lectures to some people who were learning to be doctors at a place called the College of Physicians. The lectures were to be upon the way the heart worked and upon the movement of the blood. Both having to give these lectures and having to go and give a pill to the Lord Chancellor made Harvey feel grumpy. How could he lecture on the heart and the blood when nobody really knew anything about them?

Of course he knew that everyone would think him a very good lecturer if he just repeated, as everybody else did, what Aristotle and Galen had said about the heart and the blood. Most doctors at that time thought that there were two kinds of

blood—a thick, dark, heavy sort which came from the liver, and red, hot, light blood that came from the heart. The heart, many doctors thought, was a sort of furnace that heated up the blood, while the brain was used to cool it. They knew, as we know now, that the heart had four hollows in it—two above called auricles, two below called ventricles.* Aristotle said, and Galen said, that the blood passed backwards and forwards right through the middle of the heart from one ventricle to the other ; but that was just what Harvey did not believe. They also thought the blood was always being made fresh, and came from the food that people had eaten ; but that was just because they had never made experiments. They did not know, as Harvey knew, what a tremendous lot of blood is pumped by the heart all the time. In one hour the heart pumps out so much blood that if you could collect it all and weigh it, it would weigh three times as much as the body of the person. What Harvey wanted to know was this : where did all this blood come from ?

And then, thought Harvey, crossly fidgeting on his horse, when there were important things like that, that nobody knew about the body, he had to leave off trying to find out, and to go and give pills to Lord Chancellor Bacon, and afterwards look wise in front of the medical students and pretend

* Arranged rather like the four rooms of a doll's house.

he knew all about it. The horse twitched his ears and plodded on. A man tried to sell Harvey a bit of rusty iron that had lain six years in a holy well and now was guaranteed to cure fits. The man-servant shooed him away.

Of course, Harvey was thinking, there were dozens of doctors in London and Munich and Rome, and heaps of other places, too, who were quite content to go on dosing people without knowing in the least what they were doing. If the man got well, these doctors were ready to take the credit; but as for knowing what they were doing, they were perfectly content to go on copying Galen and Aristotle. Well then, they were no more honest than the man who wanted to get him to buy the iron. Harvey had his suspicions that Aristotle and Galen, much as he admired and respected them, were wrong about a great many things. He was beginning to think he had caught them out, for instance, about this matter of the heart. Harvey did not believe that the blood passed from the right to the left side of the heart: he was beginning to think that the two sides of the heart were quite separate, in spite of anything that Aristotle might say.

'No,' he thought, 'I must go on doubting. I must not believe things just because Aristotle says so.'

For Harvey had done most of his studying to be

a doctor at Padua, the very university where Galileo, only a few years before, had been a teacher. There, those who wanted to find out were told by their teachers that they must look and think for themselves. It was because people there were ready to think for themselves that Padua had become such a great university. Harvey felt sure that Master Fabricius (his teacher) would want him to doubt. Master Fabricius had been a great one for asking questions, and cutting up dead body after dead body until he found the answer for himself. This way of finding out, he had been taught by *his* master, Vesalius, was the right way.

But the other doctors, who preferred reading books to looking at people's bodies for themselves —they also left out another thing. They never studied animals. The idea that the anatomy* of animals would be a help, was an idea that Harvey had got very clearly in his head: of course, he wasn't a vet—it was not his business to cure animals—but he knew from Aristotle, and had made sure for himself, that such beasts as sheep, and deer, and even chickens, were not so very unlike man, after all, and sometimes you could see a thing in their bodies more easily than in a man's.

Harvey gave his pill to the Lord Chancellor,

* Anatomy means the way a body is put together and what it is made of.

and he gave his lectures ; and in his lectures he hinted at something about what the heart did that he had not yet found out. This and that *might* be true, but Aristotle and Galen might be wrong.

Meantime, everybody thought Harvey a very learned doctor. He was already the head doctor at St Bartholomew's Hospital, and a famous lecturer ; and now he was appointed Physician to King James the First.

Harvey had a lot of brothers There were John, and Thomas, and Eliab, and Daniel. They were all rich merchants, who sent ships to the Indies and traded in spices with distant countries, and wore beautiful furred gowns, and were very much respected in the City. They were not so much interested in what their brother, William, thought about the heart or about where all that immense amount of blood came from ; but they were proud of him and very much pleased when he was appointed to be one of the King's doctors, and when so many of the rich people in London had him to look after them when they were ill.

And now Harvey was much respected, and might be seen at all hours, in his velvet gown, pacing soberly along on his horse, going to see the King or some rich man who was ill. But when Charles the First came to the throne, he saw that this one of

the King's physicians was somebody out of the ordinary: he guessed that Harvey was the sort of man who finds things out, and he liked to be told what work Harvey was doing. He used to let him have the bodies of deer that had been killed in Windsor Park to examine, and Harvey used to explain to him how he believed that there was not really so much difference, after all, between a man's body and the body of a deer, and how, above all, it was important not to be too sure that Aristotle was always right. Facts, he would tell the King, do not respect anybody's opinions at all. 'The things of Nature,' he said, 'bow not to antiquity. There is nothing more ancient or of higher honour than Nature.'

He went on lecturing to the young doctors and he told them strange things about the blood and the heart.

Then at last the great moment came. Harvey decided that he had really solved the riddle of where the blood came from, and three years later he told, not just his students, but the whole world, what he had found out.*

Let us suppose, he said in his book, that the big chamber on the left side of the heart only holds four table-spoonfuls of blood. The pulse beats

* This was in a book called *De Motu Cordis*, which is Latin for 'Concerning the Motion of the Heart' The whole book was written in Latin, which was then a language understood by learned men all over Europe

seventy-two times a minute, and there are sixty minutes in an hour. In the course of one hour, therefore, this left side of the heart pumps out 8,640 table-spoonfuls, and that will weigh thirty-eight stone and eight pounds—nearly three times, that is, the weight of an ordinary person. The problem that has to be solved, then, is where does all this tremendous quantity of blood come from?

'What is now to be said,' wrote Harvey, 'on the quantity and source of the blood which thus passes, is so novel and unheard of that I . . . tremble lest I have mankind at large for my opponents. So much doth wont and custom become a second nature.'

It was no good, he went on, for all the doctors in the world, with Aristotle and Galen to back them, to say that this amount of blood comes from the food and drink consumed in the time. Why, if the man were to eat and drink all day and all night, he would scarcely be able to take such an amount of stuff into his body. There is only one way of accounting for the tremendous stream of blood that passes through the heart every day and hour of a person's life.

'I began to think whether there might not be *a motion, as it were, in a circle.*'

The blood, said Harvey, circulates. The blood that the heart has pumped out through the

arteries goes out to every part of the body, hands, feet, head, stomach, liver, and bowels But most of it goes away again. It is collected again by the branching veins. Slowly and sluggishly this time, it flows back to the heart; it moves back because the clean blood from the heart is always pressing on behind it, and because there are little gateways in the veins, called valves, that will only let it flow one way, back towards the heart again.

That is the solution of the puzzle—the blood circulates, goes round and round. In one hour the same lot of blood has been round the body three or four times

Then Harvey went on to describe how, when the blood has got back to the heart, it does not go back to the left side at all, but to the right side. The right side of the heart is, he said, a quite separate pump, which sends the blood to the lungs. In the lungs it is cleaned * Then from the lungs it flows back to the left side of the heart, and the whole journey is started over again

If, then, the blood travels round and round in this way, we have not got to imagine such an absurd thing as a person having three times their own weight of blood in them Probably a boy or

* We know now that it gets a gas called oxygen from the air The air, of course, is sucked into the lungs every time you draw a breath.

girl who weighs six stone will have about six to eight pounds of blood, and a heavy man who weighs twelve or fourteen stone will have twelve or fourteen pounds of blood.*

Doctors nowadays consider that Harvey's discovery of the circulation of the blood is one of the most important that have ever been made about the bodies of men and animals. Up till then, the body had seemed such a puzzle that it was almost impossible to make head or tail of it. But when Harvey had published his proofs, though a great deal was still not understood, one large, important part of the machine was clear. This fact about the blood made sense of a great deal of the rest.

At the end of this story I have put, partly in Harvey's own words, one of the experiments by which he proved what he said; for as you will

* This is how Harvey summed up what he had to say

'Now I may give my view of the circulation of the blood and propose it for general adoption

'All things, both argument and ocular demonstration, confirm that the blood passes through lungs and heart by the force of the ventricles and is driven thence and sent forth to all parts of the body There it makes its way into the veins and pores of the flesh It flows by the veins everywhere from the circumference to the centre, from the lesser to the greater veins, and by them is discharged into the *vena cava* and finally in the right auricle of the heart. [The blood is sent] in such a quantity in one direction by the arteries as cannot possibly be supplied by the [digested] food , It is therefore necessary to conclude that the blood in animals is impelled in a circle, and is in a state of ceaseless movement , that this is the act or function of the heart, which it performs by means of its pulse, and that it is the sole and only end of the movement and pulse of the heart'

come to realize the more you read, the important thing is this proving—the difficulty is the making sure.*

CHAPTER 2

Now up to the time when Harvey had published his great discovery, he had been making a great deal of money as a doctor. But as soon as his book came out, sick people began to be afraid to come to him. John Aubrey, a gentleman who kept a diary at that time and who has left us a lot of interesting gossip, says : 'I heard Harvey say that after his book came out, he fell mightily in his practice. 'Twas believed by the vulgar that he was crack-brained, and all the physicians were against him. I knew several doctors in London that would not have given threepence for one of his medicines.'

I think we shall probably guess that these physicians were the sort who are content to look wise, and to pretend that there is the right sort of ointment for every sort of sore, the right kind of

* One of Harvey's other experiments was with snakes A snake's heart will go on beating for some long time after the creature is dead, and in snakes the big blood-vessels are very easy to see Harvey explained that if you split open a newly killed snake the heart could be seen beating, and if a snake's big vein and big artery were stopped and opened by holding them tight with a pair of forceps and then loosing them again, the heart could be made to fill and empty alternately

pill for every ache, and the right kind of black smelly medicine for every sort of fever or spot. They did not want things to be found out. However, Charles the First seems to have stuck to Harvey, and still believed in him; and in some ways perhaps it was a good thing that the sick merchants and rich people were afraid to go to him any more. For what happened was that Harvey went abroad again for a while, and was able to teach his wonderful new idea to doctors at Nuremberg in Germany, and other places.

Harvey—because he was the King's doctor—was sometimes given curious work to do besides travelling One summer, four poor women in Lancashire were accused of being witches. They were brought to London, and Harvey, the King's surgeon, and ten women who did nursing, were appointed to examine them and say if they could find anything unnatural about their bodies. But they reported that there was nothing unnatural, and so the women were all pardoned. Had they been found guilty they would have been burnt. The Inquisition and the Catholics were not the only ones who liked burning people.

But something worse than the jealousy of other doctors and the timid fears of the rich merchants put a stop to Harvey's work in London. Very serious political trouble had begun. In 1640, King Charles marched up to Scotland because

his Scottish subjects had rebelled, and Harvey went with him.

You have very likely read about Ship Money, and Pym, and Hampden, and Oliver Cromwell, in history. When Charles turned back from Scotland it was to find that his English subjects were quite as much discontented with the way he was governing, as his Scottish ones; and in 1642 the Civil War began with the Battle of Newbury.

Charles the First was at war with his people. Some took one side, some the other. Harvey took the side of Charles, who had always treated him well.

For some time he seems to have travelled everywhere with the King. Aubrey says:

'When King Charles, by reason of the tumults, left London, Harvey attended him, and was at the fight at Edgehill with him During the fight the Prince and the Duke of York were committed to Harvey's care. He told me that he withdrew with them under a hedge, and took out of his pocket a book and read But he had not read very long before a bullet of a great gun grazed on the ground near him, which made him remove his station'

I think Harvey was very sorry that the Civil War should have been fought at all. Although as a young man he had been hot-tempered, he had become very peace-loving, and really cared for

nothing but to learn more. He wrote in one of his books :

' Man comes into the world naked and unarmed, as if Nature had destined him for a social creature, and ordained that he should live under equitable laws and in peace, and as if she had desired that he should be guided by reason rather than driven by force.'

But force ruled England at that time. The King was finally driven away from London, where Cromwell and the Parliament men had formed a government, and Charles and his army made Oxford their headquarters. Harvey still attended him, but probably he thought that very little good could come to anyone out of all this fighting.

The times were very sad, as you probably know, for often families would be divided, some brothers and sisters taking one side and some the other, or a father taking one side and his son the other, and actually having to fight against each other, or batter down each other's houses.

Harvey was glad to settle down somewhere, for he had become very much interested in a new line of discovery How do creatures develop, he wanted to know ?

Now Aristotle had a long passage about eggs, and about how the yolk and white of an egg turn day by day into a chicken, with nerves, a heart, bones, blood, skin, toe-nails, and fluff. Harvey

wanted to try Aristotle's experiment over again, so when he was at Oxford he kept a broody hen in his room.

'I first saw Harvey,' writes Aubrey, 'after the Edgehill fight at Oxford, but was then too young to be acquainted with so great a doctor. I remember he came several times to our College, Trinity, to George Bathurst. He had a hen to hatch eggs in his room, which eggs he opened daily to see the progress and ways of generation.'

Harvey did not remain with the King till the end. Perhaps he thought the King ought to have given in and made peace sooner. Perhaps his brothers persuaded him to come back. Anyhow, a little while before Charles was taken prisoner and the end of the war came, Harvey came back to London. His brothers were delighted, and Eliab told him that he had invested the money that Harvey had earned as a doctor profitably, so, in spite of everything, Harvey was a rich man.

But the brothers, who had always loved each other, would not let him set up a house of his own. No—he must spend his time in their houses. Sometimes he would live with Daniel, sometimes he would live with Eliab, and each of the brothers arranged parts of their houses specially to suit their brother William. In one he had a sort of roof-garden made on the leads, where he could sit and work; in another there were cool underground

rooms where he could go if the weather was very hot, or where he could keep specimens that must not go bad.

His brothers were rich, and it was agreed that Harvey should not leave his money to them or their children, for they all had plenty to live on; so, before he died, Harvey gave all his money to the chief training-school for doctors in London, the College of Physicians. He was now too old to experiment himself, but there were always young doctors being trained there. He wanted these younger men to carry on the great work of studying the human body, and to fight the battle against ignorance and disease in which he had played so splendid a part. He had the happiness of seeing a fine new wing built on to the College, and of knowing that the truths he had taught about how that particular part of the body works were being taught to the young doctors who came after him. How great the need was for more study is shown by the terrible story of the plague of London, which happened only nine years after Harvey died.

Perhaps some readers will wonder what good it was to find out that the blood was pumped round the body. Several ways of curing fevers and so forth, a great deal of the work done for animals and human beings by such men as Pasteur and the fighters of yellow fever, really depend on knowing this. If you know that once in every two or three

hours the chances are that any particular tea-spoonful of blood will have been to almost every part of the body, you know that if something is put directly into the blood it will get sent everywhere. For instance, suppose a snake bites a person. If you know that the blood circulates, you know that one of the things you must do is quickly to get rid of the blood that is mixed with snake poison. For you know that otherwise the poison will soon be sent all over the body. But sometimes, as you will learn, it is a doctor, and not a snake, who wants to get a very little dose of something sent all round to every part of the body. Because of Harvey's work, the doctor knows that the quickest and best way to do this is not to make the sick person swallow and digest it, but to get a small dose right into the blood stream How this is done, and what it is that the doctor wants to get carried round the body, will come into later stories.

For something else about the world we live in, something of quite a different sort, had also to be discovered before Pasteur's or Lister's work could be done. The next story will tell what this was.

EXPERIMENT

(Boy Scouts and Girl Guides learn one-half of this experiment in their ambulance work)

Have ready a very big handkerchief, a scarf, or, best of all, a first-aid triangular bandage, and a short stick. Choose someone with rather thin arms with large veins on them, and ask him or her to allow you to tie the bandage loosely round their bare arm, about half-way between the elbow and the arm-pit. (This experiment is much improved if the shoulder can be bare, too, as a rolled-up sleeve is apt to interfere with the circulation quite independently)

Find the pulse, on the thumb-side of the wrist, about two fingers' breadth above the root of the thumb

Now slip a stick in between the bandage and the arm, and twist it round so as to make the bandage as tight as the person can bear it without pain Now see if you can feel the pulse

(Another way of compressing the artery is with the fingers, but for present purposes it is not so good, as it makes the next part of the experiment more difficult)

Keep the bandage on for about two minutes If you have compressed the artery, the hand will now begin to become blue and cold Now slacken the bandage, to a 'medium tightness ' The veins and arteries of the hand and arm will quickly become full of blood, and in a few moments the superficial veins will show their valves · these appear as knots. The pulse will also have begun to beat again The 'medium bandage' must not be kept on too long, as the hand will begin to swell and be very uncomfortable

Harvey has this note on the experiment. 'The difference in the effect of the tight and medium bandage is this,

The tight bandage not only obstructs the veins, but the arteries also, whereby it comes to pass that the blood neither comes nor goes to the members. The medium bandage again obstructs the veins, the more superficial among them especially, while the arteries, lying deeper, being firmer in their coats and forcibly injected by the heart, are not obstructed but continue conveying blood to the limb. Wherefore follows the unusual fullness of the veins, and the necessary inference that the blood flows incessantly outwards from the heart by the arteries and ceaselessly returns to it by the veins.'

The same experiment can be tried with the leg. The pulse at the ankle is a little harder to find. It lies just below the big ankle-bone on the inside. The veins of the leg will show more valves than the veins of the arm.

STORY IV

ANTONY VAN LEEUWENHOEK
(1632–1723)

CHAPTER I

THERE WAS ONCE a boy named Antony van Leeuwenhoek,* who was born in Holland in 1632. Some of his uncles brewed beer, some of them had farms, and some of them were basket-makers.

On Sundays, in the winter, Antony, dressed in a pair of very wide breeches, a padded jerkin, red stockings, and with a fur hat pulled tight down over his ears to prevent them from getting frost-bitten, used to skate down the long canal to see the willow plantations. Sometimes his aunts, who wore stiff white caps, gold ear-rings, and very wide petticoats, used to give him sugar buns and hot spiced beer.

The boy's parents were not at all rich, and when he was nearly grown up (sixteen) he went to Amsterdam to learn to be a shop-boy. While he was there he fell in love, and by the time he was twenty-one he had married the girl and had got a

* This word is pronounced as if it were spelt Layvenhook.

draper's shop of his own in Delft. Delft was rather a nice town, with canals and barges and a great many windmills Antony soon made quite a good living with his shop, but it did not interest him very much to sell muslin for caps to old ladies He was very inquisitive. Of course the customers who came to his shop, to buy lawn, and cyprus, and woollen stuffs, used to tell the man behind the counter a great deal of gossip, but that was not the sort of thing that Leeuwenhoek was inquisitive about.

What he wanted to know about was the spiders that spun webs in the corners, if the shop-boy did not dust properly. Their webs were not like the ones the spiders in the garden made. he wondered why? He wondered about the mussels that grew among the sea-weed at the bottom of the canals in Delft, and were sometimes poisonous and sometimes not poisonous, and about what his own blood was made of, and why it was red, and many things of that kind.

Leeuwenhoek wished very much that he could read Latin. He knew that there were books about such things, but they were all in Latin and he could only read Dutch He had had to begin to earn his living rather young, and so had not had much time to learn.

But he wanted to know these things very much indeed.

Some people said, for instance, that the little

worms that you find in rotten cheese were the smallest living creatures in the world. But were they? Some people said that if you got a unicorn horn and powdered it, and made a circle of the powder and put a spider in the middle, the spider would be unable to move. Was it true? He wanted to know how flies were able to walk on the ceiling. Surely it ought to be possible to find out these things?

The shop prospered fairly well, and Mrs Leeuwenhoek, and later the daughters, used to help him with it; so he had a good deal of spare time. Like Galileo, he had heard of a little glass that you looked through. But the glass Leeuwenhoek had heard of was one that made tiny things look twice, or even three or four times, as big as they had before. The microscope, they called it. There were only a very few of these microscopes anywhere in the world, and they could not be bought in shops. He thought he would try to learn to make one.

Antony must have grown up into rather an odd man, because he was not content with going to a spectacle maker and being taught how to grind little bits of glass into lenses. He even went as well to the goldsmiths and silversmiths to be taught how to refine metals. And when he had made his first microscope it was absolutely his own work. He had ground a little piece of glass

into a powerful but very tiny magnifying glass,* he had taken a lump of dirty-looking mineral and had melted it in the fire. He had got rid of all the stone and earth, and beaten the silver out to a fine plate ; he had set his little piece of glass in the silver plate, and arranged a screw and a clamp.

He could fix the whole thing on to a small glass tube, and into the tube he could put one of the tiny things that he wanted to study He could then look at it through the small microscope-lens

And now, with this queer sort of microscope, he was ready to see if he could not find out about all the things that puzzled him. He worked in a big room behind the shop ; and he began looking on a day when the sun was streaming in through the window He wanted all the light he could get.

He was delighted with what he saw He looked at a bee's sting He looked at fleas' eggs. He even kept fleas' eggs in his warm room, and watched the young fleas struggling out of the eggs. He looked at the green-fly from the roses in his back garden, and saw that through the microscope they were strange, transparent pale green things, with queer eyes and horns, and tubes sticking out at the back, and feet with funny claws. He thought he would like to get some of the green-flys' eggs and hatch them out, so he began looking for some. It was summer and Mrs Leeuwenhoek's roses were in a dreadful state; there seemed to be more and more green-fly every day.

* About an eighth of an inch across

But nowhere could he see any eggs! This seemed very odd. He caught some green-fly and kept a careful eye on them.

What do you think he found was the explanation of the puzzle? He found that during the summer the green-fly that grows on roses does not lay eggs at all, but is one of the very few insects that are born alive.

Leeuwenhoek began to get very much interested. He put mother green-flies into his little glass tubes and looked at them through the microscope, and he actually watched through his microscope how the children were born. The mother just dropped miniature young green-fly, which grew very, very quickly and began to eat at once.

He found that one mother might have as many as sixty young ones in the course of a day or so.

When the autumn came, however, he found another odd thing. Some green-fly began to be born with wings, and later, yet another sort (all from the same mothers) that *did* lay eggs. After a long time he found that eggs are only laid in the autumn and are meant to last out the winter, which a regular green-fly would not be strong enough to do. In the spring the eggs hatch out and the story begins again.

Soon after he began to make microscopes, Leeuwenhoek heard about Harvey's discovery of the circulation of the blood; for though he could

not read Latin himself, he had not long been making microscopes before people came to see him and told him a lot about what was going on He was very much interested, and asked a great many questions.

Somebody told him how Harvey was dissatisfied because, although he was sure the blood circulated, he had not actually seen the whole circle Leeuwenhoek, from what he heard, was inclined to think it was nonsense about the blood circulating. Anyhow, he thought, if it was true, then he ought to be able to see with his microscope the very places where the arteries and veins flow into one another in a tiny network Now Harvey had found that the arteries branched and branched and branched, and got tinier and tinier, and that the veins branched and branched and branched and got tinier to meet them. But as far as he could see, it was always quite clear which was an artery, and which was a vein. He could not see the intermediate tubes which we now call the capillaries

So one morning Leeuwenhoek stood by one of his little microscopes and wondered how to begin He looked down at his own hand He supposed that this thing that Harvey had never been able to see must be happening in his hand ; but he did not think he could catch it there with his microscope His hand had a firm skin over it , you might as well try and look through the leather

binding of a book, he thought. Besides, even without the skin, his hand was thick and dark and did not let the light through. Light was most important. If he was going to see those very tiny tubes, he must have all the light he could. He thought and thought, trying to think of an animal with some very transparent part which was yet neither hair nor nails. He had good reason to know that the blood does not flow through hair or nails. They do not bleed when you cut them, so that is proof.

At last he thought of something that would do. He knew that fish have hearts and veins, because he had cut up all kinds of fish to look. But this time there was to be no cutting. He got a tiny young fish and put it in one of his tubes. Then he clamped the microscope on in such a way that it let him look at the fish's very thin tail. There was water in the tube, and he kept the fish alive, because it was much easier for him to see the small capillaries when the blood was actually flowing through them.*

Standing by his window, Leeuwenhoek turned his screw to try and get a good focus of the fish's tail. Sure enough, after one or two tries, he saw.

What he saw was the arteries branching down and down and down till they became finer than

* You know yourself how much easier it is to see something that is moving than something which is quite still. Hares and rabbits and sitting birds know this quite well.

the hairs on the back of his hand. He saw the veins branching down and down and down till they became just as fine. And then in between, by the light that came through the transparent tail of the fish, he saw the most delicate network of all, the capillaries, the place where the blood actually feeds the body. You can imagine how very much delighted Leeuwenhoek was, and how much he wished that Harvey had been alive, so that he could have had this proof.

Of course the microscopes that Leeuwenhoek made were not nearly so good as the ones you can buy nowadays; but he was so clever at looking at things, and knew so much before he began to look, that he was able to see a great deal more with his bad microscope than I, for instance, and perhaps you (unless you know a great deal about it) can see even with an expensive modern one.

But there was one difficulty with his sort of microscope It was this—that it was very difficult to get whatever you were looking at in focus Even if you happen not to have ever used a microscope, I expect you have looked through a telescope or field-glasses sometimes. Unless you get them screwed just right, all you see is a blur and a mist. With Leeuwenhoek's kind of microscope there was only one position of the screw in which you could see your specimen at all, and once you missed it, or turned the screw half a

hair's-breadth too far, you might be hours before you could get it again. So he got over the difficulty by making dozens and dozens of microscopes. He had a shelf all round his room, and on the shelf were rows of little microscopes.

CHAPTER 2

By now, as you can guess, Leeuwenhoek was famous. Anyone interesting who came to Delft was always brought to see him and to be shown these microscopes. Everyone agreed they were the strangest and most curious things to be seen in the whole town.

One day an odd-looking man was brought to see him. He was tall, and with rough, clumsy hands as if he did hard work. He was dressed rather like the Roundheads in the pictures in a history book. Leeuwenhoek noticed that the man who came with him kept his hat in his hand all the time, but that the queer, rough-looking man kept his on. He also noticed that the rough man was rather rude to the other man, and he thought he must be a country-man who knew no better. But I think that Leeuwenhoek must have been surprised by the intelligent questions that the rough man asked, because, as he found out afterwards, the man was none other than Peter the Great, the queer, hard-working Emperor of

Russia who was so clever and so disagreeable, and who went to England and Holland to learn to be a ship-builder.

Other people besides emperors came to see Leeuwenhoek. One day it was a most intelligent gentleman called De Graaf. He said to Leeuwenhoek: 'You are finding out very wonderful things with your rows and rows of tiny microscopes, but as you don't write books in Latin about it all, a great deal of your work is being wasted. That is a pity, for I doubt if anyone in the world, except perhaps Signor Malpighi in Italy, is finding out such interesting things as you. I wish that you would write in Dutch, just as it comes into your head, about all the things that you have been doing.'

He went on to explain that if Leeuwenhoek would do this, he would send the letters on to a set of learned men in England called the Royal Society.

Leeuwenhoek asked De Graaf to tell him more about these people. De Graaf said that, as Leeuwenhoek knew, Charles the Second was the King in England then; and he was very much interested in making experiments.* He even had a little room of his own where he tried to find things out, but he was too lazy to be particularly good at it, though he was clever enough, and

* Did you try the one I told you about on page 19?

interested. But, at any rate, he did encourage other people to find out ; and people were mad about making experiments in England just then. The great architect, Sir Christopher Wren, for instance, who designed St Paul's, and Chelsea Hospital, and was the King's architect, was always finding out things about the moon and stars, and he made a queer kind of clock for the King as well. Then there was a Mr Boyle, who was so good at making chemical experiments, and who sometimes blew things up. In short, the members of the Royal Society were men who were always trying things—all sorts of odd things—just as Leeuwenhoek was.

De Graaf said that the Royal Society had even tried the experiment with the spider. They had bought what the man who sold it swore was real unicorn horn : they had powdered it, they had made a circle of the powder, and they had caught a spider and put her inside the circle. But she had run out instantly, none the worse.

De Graaf said they had people writing them letters from all over the world. This Signor Malpighi, who also used a microscope, wrote to them, for instance ; did Leeuwenhoek know that Malpighi had seen the capillaries in a frog's lung, just as Leeuwenhoek had seen them in a fish's tail ?

De Graaf was a very interesting man, and

Leeuwenhoek agreed that he would become what was called a correspondent of the Royal Society. So now he began a long series of letters, which he called *Secrets of Nature*. These letters were about everything you can possibly think of that grew, could be got, or could be fished or dug for, near Delft in Holland. Leeuwenhoek just wrote down whatever came into his head—whatever he had discovered. Sometimes it would be about spiders, sometimes it would be why the herrings came up into the shallow water and were caught by the fishermen, about fleas, about shrimps, about bits of his own skin, about what the codfish were after when they swam up near the land.

To find that out he would open dozens of the fish himself, instead of letting the fishermen clean them, and like that he would find out what the fish had been eating. Or another time he would write to the Royal Society about the leaves of trees, or nettle stings, or the different look of a hair from his moustache, one from his head, and a tiny hair from the back of his hand.

It was not long before he sent a beautiful present to the Royal Society. He described the present himself in a letter :

'It is a small black cabinet, lacquered and gilded, which has five little drawers in it, wherein are contained thirteen long and square tin boxes

covered with black leather. In each of these boxes are two ground microscopes. There are six and twenty in all, which I did grind myself and set in silver, and most of the silver was what I had extracted from minerals and separated from the gold that was mixed with it, and an account of each glass goes along with them.'

He had put the things to be looked at ready in glass tubes or stuck on pins, so that the people at the Royal Society could not make a mistake by not adjusting the screws right.

I went to the Royal Society to see if I could see this beautiful box. But I am sorry to say that some old gentleman borrowed it about sixty years ago; then, it seems, he died, and nobody knew how old and valuable it was. So it disappeared and is now lost. But they were very kind, and showed me Leeuwenhoek's letters, written in a very neat, clear hand in Dutch. With a great many of the letters there were little square bits of paper folded up, with the dry old bits of leaf or skin or fish-scale still in them that he had sent for the Royal Society to look at in the days of Charles the Second. It seemed to me strange, and rather wonderful, to see and gently touch leaves that Antony Leeuwenhoek had picked in Delft so long ago.

CHAPTER 3

One day Leeuwenhoek could not think what to look at next. He seemed to have looked at everything; but he had made himself a particularly good new microscope, and it was a bright day. This made a great difference, because, as has been said, with his sort of microscope it was only possible to see well in bright sun. So he went out into the garden, and there was an old pond, and he thought he would look at pond water and puddle water. Of course there were all sorts of little bits of plant, and an odd spider or so, and a good many things that you could see with your eye, for it was very dirty water But he got rid of all this before he began to look through his microscope. He arranged so that, with his eye, it simply looked like cloudy puddle water.

Then he began looking at the water through the good new microscope in the bright light. What do you think he saw? He saw that the water was full of tiny creatures—creatures so tiny that it seemed impossible to believe they were alive.

'Why, oh why,' he said to himself, 'have I never looked at puddle water before?' It was simply marvellous. There were two beasts with forked tails—one seemed to be red and one green. These creatures had something on their heads

with which they beat about and made a whirlpool He saw another beast with six or eight horns; he saw queer green discs that floated along and divided into little discs; he saw creatures like poppy heads and tiny lumps of jelly with a dark spot in the middle of each. Some seemed clearly to be animals, and some seemed more like plants.

This was about 1683. Leeuwenhoek had made a great discovery: he had discovered a whole new world, the world of life that is too small for us or any regular animal to see—'Sub-visible,' it is called

He wrote at once to the Royal Society about it. It was his most wonderful discovery of all He tried all sorts of experiments, and found out a lot more. He found, for instance, that there were no tiny beasts in absolutely fresh rain-water that had been caught in a clean dish in the garden, but that rain-water that had stood in a tub for a few hours was full of beasts and plants. So was the water that ran down the gutters off the roof; so was the water in the canal.

Now this great discovery of creatures too small to see, suggested something to Leeuwenhoek that he very much wanted to know. I said that there were mussels in the canals at Delft or just outside it. Well, a great many people thought that such creatures as (say) fleas, cheese mites, and mussels, did not need to have parents. They saw that

there was some connection between fleas and dirt, and they thought dirt just turned into fleas. They knew that there was some connection between mud and mussels, and they thought that mud turned into mussels when the sun was nice and warm. I know people who to this day think that mud in ditches turns into frogs.

Leeuwenhoek was perfectly sure that nothing of the sort happened: he said that he would find it as easy to believe that a whale had no parents and was formed out of sea-sand, as that a mussel had none. He knew too much about how elaborate and beautifully made such a thing as a flea is—or any living thing.

Most people to whom he showed his new-found tiny beasts found it quite easy to believe that they, at any rate, had no parents; but Leeuwenhoek would believe nothing of the kind. The tiny beasts, he felt sure, had parents just as mussels had parents, just as whales had parents. The question was, if they did not just grow of themselves, where did they come from, and how did they get into the rain-water?

The tiny beasts certainly behaved very oddly. For instance, they could be completely dried up without dying. Leeuwenhoek was a quiet, patient man, and he tried this experiment. He examined the water from a muddy puddle: it had the beasts in it. He let the water all dry up

out of one of his little glass tubes, but he kept the mud at the bottom. He kept this tube for nearly two years: then he took some absolutely clean rain-water, examined it through one of his microscopes, and saw that it had no creatures in it. With this clean water he moistened the mud that he had kept for two years. In an hour, when he looked down the microscope again, the moist mud was full of these queer tiny beasts with forked tails and windmills on their heads! He realized that they or their eggs had remained dried all this time, but as soon as there was moisture they woke up out of their long sleep.

We know a little bit more about it now. Since Leeuwenhoek's day people have watched these small animals with powerful microscopes to see exactly how they manage this drying. It seems that they have a skin which prevents them from really drying up. When the water they are in is drying up, they shrink down to be even smaller than they were before. Their mouths, and any other holes in them, seal themselves up with wads of jelly, and this prevents the moisture leaking out. Thus the little beast itself is able to stay wet inside its skin. But it has been found possible to dry the little creatures so quickly that they do not have time to shrink up and make jelly wads. If they are dried as quickly as that, they die.

Leeuwenhoek began to look for his beasts in all kinds of odd places; he looked at little bits of food that got stuck in his own teeth, he looked at blood and at bad meat. He wrote fast at his *Secrets of Nature*. The tiny beasts lurked in all sorts of odd places.

It was some time before the people at the Royal Society would believe what Leeuwenhoek had told them about the tiny beasts, and he was very indignant over this. He had never told them lies, he said They knew that he had never told them lies; and here they were—not believing what he said! But it all came right in the end, and when the Royal Society found that he was right and they were wrong, they sent him a beautiful diploma and a huge medal, and he hung them up very proudly in his back room.

Leeuwenhoek was getting an oldish man now, and one of his daughters was very good at helping him with his work. She used to enjoy watching the little wriggling beasts, and would sometimes stay watching with him hour after hour. I don't know what her name was, but she must have been nice.

Leeuwenhoek still went on writing his long series of letters about the Secrets of Nature. He wrote altogether nearly two hundred of them about all kinds of things. Before he died there were three things he believed, because of what he had seen down his microscope.

One thing was the circulation of the blood: he had seen it happen in that fish's tail, and other people had seen it too.

The second thing was that there is life everywhere. There are little plants—yeast plants, for instance—so tiny that we cannot see them: there are little beasts in the rain-water so tiny that we cannot see them. These beasts and these plants can stand drying, and can be blown about by the wind in dust, or carried in mud on people's shoes, or even on a bird's feet or wings. This, like the circulation of the blood, Leeuwenhoek made a lot of other people believe, too.

But what he could not make them believe was the third thing, which, as you will hear, was not believed even long, long afterwards, quite into the time that living people can remember; and that was that these tiny beasts of his, and the much tinier beasts that were found afterwards, all, without exception, have to have parents. Leeuwenhoek was sure of this, but nobody else was.

But there was one odd thing Nobody at that time thought at all whether the little beasts and the little plants did any harm or any good to bigger animals such as man.

It was not till a long time afterwards, as you shall hear, that it was found that tiny beasts do a great deal both of good and harm.

Some do good to bigger animals, some do

neither good nor harm; but some germs, or microbes, or bacteria as they are called, give distemper to dogs, anthrax to cows and sheep, plague to rats and men, and a thousand other diseases.

It is not so long since man began to hunt the ones that do him and his animals harm. You can read in this book about the beginnings of that fight. Perhaps your great-grandchildren will read about the end of it.

STORY V

MICHAEL FARADAY

(1791–1867)

CHAPTER I

IN THE YEAR 1794 the Revolution in France was not yet over, and Napoleon Bonaparte was still a very poor and very young officer of artillery. The first cotton mills were being built in Lancashire, and the first steam-engines were being used to pump the water out of a few English coal-mines.

In London, in a poor street near Manchester Square, there lived a little boy. His name was Michael, and he went to a school with his brother Robert It was what was called a 'dame school.' The Dame who taught in it happened to be a bad-tempered woman, and she got angry one day because Michael couldn't say his 'r's' properly and would talk about his brother 'Wobert.' She raged and stormed, and said that he only said 'Wobert' because he was naughty. At last she said she would make an example of him to the whole school.

So she gave 'Wobert' a halfpenny to go out and buy a cane to beat his little brother. But Robert was a very nice boy, and he was furious. No sooner was he out of school than he pitched the halfpenny over a wall, and ran straight home and told his mother. She luckily was quite on their side. She came to the school, scolded the Dame, and took both the boys home They never went back to that school again.

The little boy was Michael Faraday, who later became one of the greatest scientists in England. His work had to do with chemistry and electricity, so that in this story we get right away from doctors and microscopes.

Michael and Robert Faraday's father had been a blacksmith, but he was dead, and they and their mother were very poor, so when Michael was thirteen he left school altogether, and went as errand-boy to a bookseller in Blandford Street in London. Michael used to get up early and carry round the newspapers in the morning He had curly brown hair and very bright eyes, and he used to rush along very fast with a big packet of newspapers under his arm. Newspapers often cost a shilling or more in those days, instead of a penny, so two or three people often shared a paper. Sometimes they just paid for a read of it. Michael often had to go back in the evening and collect the copies again.

There were very exciting things to read about in the papers that Michael carried round. The news on most days would be about the wars with Napoleon. One November day there came through the news of the battle of Trafalgar.

Then there would be something about the new factories. People were leaving the country villages and going to work in the new mills, and all sorts of ideas were stirring. The new mill-hands were terribly poor and lived in miserable houses; sometimes they grew angry, and then there would be news of riots in the papers.

He was a very good errand-boy, and hardly ever forgot things. So after he had been taking round papers for a time, his master said that he was willing to teach him to be a bookbinder, stationer, and bookseller like himself.

Faraday was pleased, and learned to bind books. Some of the books given him to bind were novels. One was a rather famous one called *Evelina*, but some of them were books about electricity and chemistry. While Michael Faraday was binding books he generally also read them. These scientific books described curious experiments and the wonderful things that could be done. Many liquids, he read, could be changed from one colour to another by the addition of a white powder: it was possible to make various sorts of crystals, big ones or little ones as you preferred, and you could find out, like

a detective, what some unknown stuff in a bottle might be. There were tests for all sorts of things, and it was easy (if you knew how) to find out, for instance, if an unknown fluid was acid like vinegar or alkaline like soda. It was possible, too, to make all sorts of gases.

Michael Faraday wished very much that he could do the experiments that he read about. One day he heard that some lectures were to be given about this sort of thing, but that it would cost him a shilling a time to go in. Michael Faraday could not afford this. But once more the excellent 'Wobert' helped. His brother was now quite grown up, and had become a blacksmith like his father. He was very kind, and gave Michael the money to go to twelve or thirteen lectures. It was well worth it, for Michael enjoyed the lectures very much indeed. He wrote down everything that he heard, and he met a lot of other young men there who were interested just as he was. The young men all agreed to form a debating society where they could discuss what they had learned and, as well as they could, teach each other and find out. They were too poor to go to a university or even to get a teacher occasionally. Michael bound his lecture-notes in some odd pieces of leather that were lying about in the shop.

But those were not the last lectures Michael Faraday heard. One of the customers who used to

come to the shop belonged to a body called the Royal Institution, whose members were rather like those of the Royal Society with which Leeuwenhoek corresponded. This customer was a pleasant fellow, and one day he got talking to the shop-boy. Rather to his surprise he found that this boy had already read and thought a lot, and was anxious to know more. So he took him to hear lectures by a famous man named Sir Humphry Davy. The lectures seemed to Faraday wonderful—so wonderful that he made up his mind that if ever he could, he would leave off being a bookbinder and spend the rest of his life making experiments.

Time went on, and he got to know the famous Sir Humphry Davy by writing to him, and by sending him the beautifully written and bound notes he had made of his lectures. Davy was pleased.

Faraday told him presently that he very much wanted to leave trade. Faraday said he felt sure that trying to make money was vicious and selfish. He wanted, instead, he said, to become a scientist, for he felt sure that such people—people who were trying to learn and find out—must be much more amiable and unselfish than people who were only trying to make money. Davy said he was not so sure.

One night, after he got back from the stationer's, Faraday and his mother saw a hand-

some coach driving up. To their great surprise, when the footman jumped down, it was at their door that he knocked. He brought a note asking young Faraday to come round next day and do some work for Sir Humphry Davy.

What had happened was that Davy had been making an experiment and there had been an explosion. He wanted Faraday to come and read some scientific books for him and attend to clearing up the laboratory, for, owing to the explosion, his own eyes would be too painful to use for a day or two. Michael Faraday came, and did the work so well that very soon Davy said he could have twenty-five shillings a week and two rooms to live in, if he would come and work for him at the Royal Institution. So in that way Faraday left the book-binding trade for ever.

Time passed, and presently Sir Humphry Davy had to go abroad. He wanted to meet a lot of other scientific men who lived in France, Italy, and Germany. There was a Monsieur Ampère in Paris, there was a Count Volta in Milan, and a lot of other important people. Davy would be making experiments, and wanted his assistant Faraday with him.

This was a tremendous piece of luck for Faraday. He went abroad with Davy and saw all the best experiments and heard about all the interesting things that were being done on the Continent. It

was on this tour that iodine (which you may have heard of) was discovered and named: part of the work was done by Davy with Faraday to help him.

There was only one thing which was rather horrid. Sir Humphry Davy's valet wouldn't come with him, and Faraday had to do some of the valet's work, which was hateful, as he had a great deal to do already looking after the papers, and packing and setting up the instruments. Besides, Lady Davy, who went too, was very disagreeable, and over and over again made Faraday run about and do shopping and errands for her, when he ought to have been making experiments or writing up notes, or enjoying himself.

However, though sometimes he was rather miserable, Faraday thought it was wonderful to cross the sea, and he very much enjoyed himself. France and England were supposed to be at war, but (very sensibly) nobody seems to have made any fuss about Faraday and Davy travelling. We have got much fiercer over our wars since then, I am sorry to say: such a thing would have been impossible in the last war.

Faraday noticed everything as he went along. He thought how thin the pigs were in Normandy, and he saw a glow-worm. He thought it was queer to see people cooking on wood fires and using charcoal in stoves, and to see women washing their

clothes in the river, which, as you probably know, they do in France to this day. There was one other strange thing, too, that Faraday saw when he was in Paris.

One day, as he was walking along the street, there was a clatter of horses. He saw mounted soldiers trotting along very quickly. A great gold coach followed them, and in the corner of the coach sat a small, pale-faced man, his body almost hidden by an enormous robe of ermine, and his face shadowed by a great plume of feathers. Faraday took off his hat with the rest. It was the Emperor Napoleon.

But when they left France, went to Italy and reached Florence, Faraday saw something which seemed to him more wonderful even than the great Napoleon. This was Galileo's telescope—that simple tube of cardboard and wood, with the lenses at each end, with which Galileo had (as he said) 'enlarged the universe a hundred-fold.'

Davy and Faraday and the other scientists had great fun going to parties all the evening and doing experiments all day.

They got home in the April of 1815. This, as you may know, was the year when Napoleon (who had been banished to Elba since that day when Faraday saw him in his coach) came back. For a hundred days he was once more Emperor of

the French, and was at last beaten in the Battle of Waterloo. But wars and battles, generals and emperors, did not much concern Davy or Faraday.

Other things that happened outside their laboratories did, though, and they found there was a difficult piece of work waiting for them when they returned.

I said that factories were beginning to grow up in Lancashire when Faraday was born. At first these factories were worked by water-power; but by 1815 steam engines were beginning to be used, and iron was being smelted to make them with, and for many other purposes. Naturally a great deal of coal was wanted for the iron smelting. The consequence was that coal mining had become one of the most important industries in the country.

But mines, of course, are dark, and, as you may have heard, a gas collects in many of them which has got the name of 'fire-damp.' (This same gas, when it rises off marshes, is called 'marsh-gas' or 'will-o'-the-wisp.') The miners had to have lights to do their work in the mines, and this 'fire-damp' was always catching fire from the lamps and candles, and blowing them up. There was quite a big loss of life from this. The mine-owners often tried to suppress the news of these accidents, and pretended that everything was all right; but a sort of club was formed to protect the

miners, and to see if some kind of lamp could not be invented which would not set light to the fire-damp. The people who belonged to the club asked Sir Humphry Davy what he could do to help them.

Davy went to see a mine where there had been a particularly bad explosion, collected some of the gas and took it back to his laboratory After trying a great many experiments he found that the gas would not explode if the flame of the lamp was shut off by a very fine wire gauze and, after several false tries, he and his lab assistants made a lamp that could be safely used even in the most dangerous mines.

Till a few years ago 'Davy Lamps' were still in use all over the world, though nowadays miners generally use an electric torch made rather like a bicycle lamp which they wear in their caps, so as to leave both hands free

CHAPTER 2

It was while they were experimenting with the lamp, that Faraday fell in love with a girl named Sarah, and married her. I think she must have been very nice, for they were fond of each other to the end of their lives. She came to live with him in the two little rooms he already had at the Royal Institution: there they lived for a long time,

although Faraday was soon a very celebrated man. They were both very religious and went to chapel regularly all their lives.

Faraday used to give lectures at the Royal Institution, and he was such a good lecturer that everybody crowded to hear him. People said that if he gave a lecture about some experiment of his own, it seemed as if he was simply trying to let his audience judge whether his experiment had been any good or not: he never made people feel that they were ignorant and that he knew everything. If he was lecturing about somebody else's experiments, it always seemed as if he admired the man who had made the experiments very much.

By now, when he had been married a year or so, it had become quite easy for Faraday to earn a very good income. People were willing to pay him for giving lectures, and besides that, there was work which he could always do in connection with the Law Courts. But though it seemed very nice at first to have more money, his wife Sarah was very economical, and never seemed to want much, and if he did this work that paid him so well, it meant that he had not nearly enough time for his experiments. So he gave up the work that brought in the money and got on with the work he really loved.

Just about then a man named Oersted in Copen-

hagen had discovered that it was possible to make a compass go wrong by running an electric current near it, and several people in different countries (as Faraday had found in his travels) were busy bringing together magnets and electric currents in the hope that something would happen.*

If you try the experiments at the end of the story you will notice that what you are doing is this. You are making things (the brown paper, for instance) into magnets by electrifying them. The experiments prove that electricity and magnetism have something to do with each other. It was on the connection between electricity and magnetism that Oersted and Faraday and several others began to work.

Faraday devised several experiments to test his own and other people's theories as to what happened when the electricity made the compass go wrong. Without a lot of pictures and a great deal of explanation I couldn't tell you exactly what it was that Faraday did, but it was something like this:

He found that if you had a very strong magnet, and then moved, say, a coil of copper wire about near it, an electric current began to flow round the copper wire. The same thing happened if you moved the magnet. The electric current only

* The force which sends the compass needle round till it points to the North is the earth's magnetism

began to flow just at the moment when either the wire or the magnet was moved. It took him some time to find this out, as it was quite unexpected.

Faraday found in the end that if you had a lot of copper wire, and a very powerful magnet, and if you moved them very often, you could make a very great deal of electricity, much more than anyone had made before. This was very important. Before Faraday's time it had only been possible to make a very tiny amount of electricity, so that electric currents were just regarded as interesting toys. Count Volta, for instance, made his electricity with a little pile of coins of different metals, each with bits of damp and salty rag between. The very best way they knew was with what are called 'wet cells.'*

But now, with his coils of wire and his magnets, Faraday had invented a new and much more powerful way of making, or as it is called 'inducing,' an electric current. This was, in fact, the discovery for which he is most famous. From the beginnings of this thing that he made—his 'induction coil'—have grown the giant dynamos and electric motors of to-day.

But it was some time before the discovery grew. Faraday himself only used electricity for his chemical discoveries. He used it in this way.

* Wet cells are used for electric bells to this day

He and Davy knew that if an electric current is run through water in which several different chemicals are dissolved, the electric current will separate some from the others. Later on discoverers found a further use for this, too. The current not only separates things out, but makes certain metals cling to certain other metals. You have seen 'electro-plated' spoons and forks and bicycle handle-bars. That is how the electro-plating is done. The silver or white metal is 'laid down' on the fork or handle-bar by the force of an electric current.

Faraday would be very much surprised if he could see all the uses to which electricity has been put now, with the help of the later discoverers who have worked at it.

Tens of thousands of people are carried every day in electric trains; schools, houses, factories, and streets are lit with electric light at night. Although motor-cars and aeroplanes are worked by petrol, yet (as any boy knows who understands cars) they would be very clumsy things if it were not for the electric spark which is used for setting fire to the petrol gas. Ironing, cooking, the cleaning of rooms, the cutting up of roots or chaff for cattle, and the milking of cows, are all either done, or made easier to do, in many countries by the help of electricity; while perhaps the things that would astonish Faraday most, if he

could come back, would be the telephone and wireless. Electricity is, in fact, the best and strongest servant Man has ever had to work for him.

Even now there are still a great many more uses to which electricity could be put, and perhaps the day will come when this strong servant will do nearly all the hard, rough work of the world.

This invention of the induction coil was not by any means the last of Faraday's experiments and discoveries, though it was in some ways the most interesting to us. I would like to tell you about just one more, however. He proved once and for all (by an experiment with stuff called chlorine) that gases can be turned into liquids, and liquids into gases. Before that it was thought that gases and liquids were two different things altogether; but Faraday proved that they were only what is called 'states' of the same thing. Ice is one 'state' of water, water is another, and steam is a third 'state' of water. The same transformations happen with many other things, as Faraday was able to prove.

Faraday lived on for years and years at the Royal Institution with his kind wife, Sarah. They had no children of their own, but one of the things he did was to start a set of lectures about science specially for children Children's lectures are

given in the Christmas holidays to this day by various scientists. I expect a great many children decided to be discoverers themselves after hearing the lectures and seeing the beautiful experiments that Faraday invented.

He himself was an extraordinarily good lecturer. He used to write down rules for himself, such as 'Never repeat a phrase.' He hardly ever just told his hearers about an experiment, but always if possible showed it to them, however simple and well known it might be. One day he was advising a young lecturer, and he said to him: 'If I said to my audience: "This stone will fall to the ground if I open my hand," I should open my hand and let it fall. Take nothing for granted.' One of the lectures for children that he gave was called 'On the Chemistry of a Candle.' He also did some lectures on metals that the children enjoyed very much. Somebody wanted him to publish them in a book. But he said that they would not be much good in a book without the experiments. Besides, he said, he was very busy doing his own work and finding out fresh things. 'I do not desire to give time to them, for money is no temptation to me. In fact, I have always loved science more than money . . . I cannot afford to get rich.'

Faraday lived to be quite an old man, and in his last days was very feeble. Everybody loved and

honoured him, and he was given medals by nearly all the universities and learned societies in the world. Quite at the end of his life he was given the use of a set of beautiful rooms in Hampton Court There he lived till he died, peacefully and honoured, but too old and tired even to see how the work in which he had helped so much was being carried forward by younger men.

EXPERIMENTS

Choose a dry day for experiments on electricity Dry everything used on a hot-water radiator, or by the fire. These experiments are best done in dry weather, but if the warming and drying is done thoroughly, can be successful even on a damp day

I

Dry a sheet of brown paper, hold it against the wall or on the table Brush it hard with a clothes-brush Tear up some scraps of paper and put them on the table Now hold the brushed sheet of paper over the scraps and lower it slowly. The scraps of paper should dance up and down between the table and the electrified sheet.

Re-electrify the paper, and repeat, using feathers. Repeat, with thin strips of tin-foil (off chocolates)

II

A HAIR-RAISING EXPERIMENT

Quickly comb the fairly long hair of a boy or girl Hold the newly electrified paper above it as before. Some of the hair should rise up and follow the paper as it is moved from side to side.

STORY VI

CHARLES DARWIN

(1809–1882)

CHAPTER I

NEAR SHREWSBURY, while Michael Faraday was still working for the bookbinder in London, there lived a doctor called Robert Darwin, who had a family of six children. The baby who was born in 1809 was named Charles by his father and mother. They all lived in a big brick house, which had plenty of trees near it and which was also not far from the river Severn.

As Charles grew older, he became a great one for collecting birds' eggs, though he never took more than one from a nest. He knew where every kind of bird and beast was to be found in the fields and woods round Shrewsbury—badgers, goldfinches, otters, nightjars, foxes, and many others. He was the sort of boy who knows a great deal about what goes on in the woods at night. He had an elder brother, of whom he was very fond, and these two used to go together to a day school in

Shrewsbury. But it was the sort of school that we should not consider much use in these days, for the boys were hardly taught anything except Latin, Greek, and mathematics.

But their father, Dr Darwin, had done experiments as a boy, and I suppose he told his sons about them. At any rate, Charles and his brother used to be always doing experiments in a tool-house at the bottom of the garden. Very often Charles would sit curled up in a corner of the shed, reading *The Wonders of the World*, while his elder brother did experiments and made gases.

Charles collected shells, and minerals, and beetles, as well as bird's eggs (There were no postage stamps in those days.) He was out of doors a great deal, and in the winter he used to wear a beaver hat, a coat with a high collar and big pockets, and long buttoned leggings His father taught him to shoot.

He was growing up, and it would soon be time for him to decide what he was going to be when he was a man. His father said that he had better be a doctor : other people thought it would be better for him to be a clergyman. But somehow he did not like the idea of either. Though he did not mind shooting birds, he did not like to see anything or anyone in pain. This made it difficult for him to be a doctor. For in those days they had no anæsthetics. People felt what was being

done to them, and so in some ways it was very unpleasant to be a doctor.

Charles certainly did not want to be a clergyman, because as far as he could see, that meant settling down in one place. He wanted to do something more adventurous. His father was getting worried about him, and told him he would never be any good, if he went on caring for nothing but rat-catching and shooting and looking after dogs.

Well, he went to college at Cambridge. There, though he learnt a great deal more about beetles and birds and earth-worms, he also got particularly interested in questions about how the earth is made—about rocks, mountains, river-beds, and so forth. People were getting exceedingly busy about geology at that time. A great many people had begun to feel less sure that the earth had really been made in six days, even if you stretched days to mean centuries. Geologists began to see from the look of the rocks, and meadows, and sea-shores, and mountain-sides, that the hills and valleys of the earth had taken thousands of years to shape All these new ideas Charles studied, and he learnt a great deal more about creatures besides.

Just as he finished at Cambridge, and it really began to be serious that he should not have settled upon any profession, Charles heard a piece of news.

It seemed that a ship called the *Beagle*, a ten-gun brig, was going to sail round the world, and to be away for five years and spend most of her time off the coasts of South America and among the Pacific islands. Her chief work was to correct old charts, and make fresh ones where the coasts were uncharted.

But the captain, whose name was Fitzroy, said there ought to be a naturalist on board. The Government said, 'Nonsense'; but still he went on saying that there ought to be a naturalist on board. They were sailing to the most queer, out-of-the-way places: they would pass by the jungles of the Amazon, sail right down nearly to the South Pole, up the coast of Chile, then on and round to New Zealand and Australia, seeing all the islands they could on the way, and charting the rocks They would go to places where ships very rarely called and where a good naturalist might find a great deal that was new.

It ended by the Government saying they would not pay a naturalist; but if Captain Fitzroy liked to find one who would come for nothing, and sleep in the other bunk in his cabin, well, then, he might do as he pleased.

Charles Darwin heard about it through the man who taught him natural history at Cambridge. He thought how wonderful it would be, and at once made up his mind that he would offer to go. Then

he needn't decide for five years whether he was to be a doctor or a clergyman.

His father said it was a ridiculous idea. 'But,' he said, 'if you can find one sensible man to agree with you and say it's a good idea, then you may go.'

Charles went straight off to his favourite uncle, Josiah Wedgwood. Everybody agreed that Josiah was very sensible and very rich. Luckily for Charles, he said he thought it was a very good idea indeed. Dr Darwin was a man of his word, and since Charles's Uncle Josiah agreed with him, his father said he might go.

It was a wonderful chance for a naturalist. Do look at the picture of the *Beagle* at the beginning. I should guess that she is just making sail. The natives in the boat are very much surprised. I wish we had been able to put in a picture of Captain Fitzroy, because I think he must have been a very remarkable person. For one thing, it was very excellent of him to see that a naturalist ought to sail with him, and to take so much trouble about it. Then, he himself seems to have known a certain amount about beasts, birds, and beetles, and a little about geology. He had rather a temper, but was a fine officer, and at his own job of chart-correcting he must have been very good. He was exceedingly conscientious and careful in all his observations.

CHAPTER 2

There was a long delay in setting sail, as they were held up by contrary winds in Plymouth ; but at last the anchor was weighed and they were off. The first land they made was Tenerife. Charles had always very much wanted to see this extraordinary island, for the geologists to whom he had listened at Cambridge had all sorts of theories as to why it happened that here, suddenly, a high mountain should stick sheer out of the sea. The *Beagle* did not have to make any chart corrections there, but Captain Fitzroy had promised Charles that if it were possible he would put him on shore for an hour or two to make geological observations. To Darwin's great disappointment, however, they were not able to land, being kept off by contrary winds.

From there they made sail towards South America, and sailed down past where the Amazon rolls out its great muddy waves, and the sea is stained for miles beyond the estuary. Up the Amazon it was hot and sultry. The heavy dark woods were almost silent by day, but strange orchids gleamed through the dark of the trees, and butterflies as big as plates flapped their painted wings slowly, and little humming-birds with their long beaks darted to and fro.

But, at that time, they did not stay long in the Tropics. They sailed down and down. The weather got colder and colder, and now very often, when they woke in the morning, the whole of the *Beagle's* rigging would be white with frost, and her sails frozen so stiff that the men had to bang them with marlinspikes before they could bend them. They were feeling the icy breath of the South Pole.

When they landed, it was to find a dismal mountainous country, over which gales, with rain, hail, and sleet, seemed never to cease blowing. It was summer, yet every day snow fell on the hills, and in the valleys storms of rain and sleet. The trees were low and bushy, and a curious dark green in colour.

Wild naked people lived in this land. Sometimes they would come out in canoes to look at the *Beagle*. Charles was amazed to see them. You must remember, he had never been out of England before. There were not so many adventure stories then as there are now, and I expect he had not read much about savages except in *The Wonders of the World*. This is one of the things he wrote about them in his journal:

'A group of Fuegians, partly concealed by the entangled forest, were perched on a wild point overhanging the sea. . . . It was without exception the most curious and interesting spectacle I ever beheld: I could not have believed how wide

was the difference between savage and civilized man. . . . The party altogether closely resembled the devils which come on the stage in operas. . . . Some Fuegians who came out in a canoe were quite naked. It was raining heavily, and the fresh water, together with the spray, trickled down their bodies. In another harbour not far distant a woman, who was suckling a recently born child, came one day alongside the vessel, and remained there out of mere curiosity, whilst the sleet fell and thawed on her naked bosom, and on the skin of her naked baby! These poor wretches were stunted in their growth, their hideous faces bedaubed with white paint, their skins filthy and greasy, their hair entangled, their voices discordant, and their gestures violent. . . . The different tribes when at war are cannibals. . . . When pressed in winter by hunger, they kill and devour their old women before they kill their dogs; a boy being asked by one of our officers why they did this, answered: "Doggies catch otters, old women, no."'

But Captain Fitzroy and his ship's company did not stay all their time in the frozen Tierra del Fuego. They sailed back to the Amazon region during one part of their time, and on to the Chilean side at another, besides calling at the cold Falkland Islands on the Atlantic side and the warm Galapagos Islands on the Pacific side.

The great Brazilian forests in the Amazon basin are very surprising places. So thickly do the trees grow that in the forest itself it is nearly dark. Not

only do the great trees themselves interlace their branches, but these branches are festooned by all kinds of beautiful climbing plants. Exquisitely scented orchids hang down their flowers, great butterflies float silently through the scented air, and humming-birds dart and flash.

'Delight itself,' wrote Darwin in his journal, 'is a weak term to express the feelings of a naturalist who for the first time has wandered by himself in a Brazilian forest. The elegance of the grasses, the novelty of the parasitical* plants, the beauty of the flowers, the glossy green of the foliage, but above all, the general luxuriance of the vegetation, filled me with admiration.'

Collecting insects was Darwin's chief occupation for about three months of his time here. He watched the habits of the many kinds of butterflies, of tropical ants, and of phosphorescent insects. Here for the first time he saw the sphex, an insect like a wasp, which builds clay cells for its grubs, and as food for them brings half-dead spiders and writhing caterpillars. These the parent sphex has stung very carefully, in such a way as to leave them quite paralysed yet still alive, so that they shall remain nice and fresh for the grubs.

Some part of the time they were in Uruguay. To his surprise, Darwin noticed that this country

* A parasitical plant is a plant which grows, not on soil, but on another plant or on a tree

is almost entirely treeless, although it is a damp, warm land where you might have expected to find plenty of trees. Here he found several strange animals, including the Tucutuco, a rat-like creature which lives underground and is nearly always blind.

But live animals, birds, and insects, were not the only things that Darwin found. He found the bones of many extinct creatures. There was, for instance, a strange creature as large as a camel but more like a llama. There were beasts like enormous armadillos, and a queer creature called the Toxodon. When alive the Toxodon must have been as large as an elephant. Judging by its teeth, it seemed to be a close relation of such animals as the deer or the cow, but in other ways it was more like a rhinoceros or an elephant, and in yet other ways—for instance, in being able to shut its ears and nostrils—it was more like a hippopotamus. 'Formerly,' wrote Darwin, 'this Continent must have swarmed with great monsters.'

He was amazed at the number of different kinds of living beasts and insects that he found. One day he easily collected sixty-eight different sorts of minute and dull-coloured beetles, besides thirty-eight kinds of spiders and plenty of butterflies.

His story of the voyage of the *Beagle* is so amusing as to be very well worth reading. His account of the queer inhabitants of different parts

of South America is just as entertaining as his descriptions of the thousands of birds, insects, and beasts, of his own adventures, and of the weather. *The Voyage of the Beagle* is a famous book, and can be got from libraries, or bought cheaply in the Everyman edition.

Time passed. Darwin had been travelling now for nearly four years, sometimes in tropical forests, sometimes in dreary plains and amongst swampy islands, sometimes among the cold, frowning mountains of the tip of the Continent.

Now up to that time everybody thought that each kind of animal had been specially created by God on purpose to live in a particular sort of climate and place. It did not seem at all difficult to believe this, as there seemed to be only a reasonable number of creatures. You see, there were not, after all, so very many travellers, and if travellers brought home animals for people to see, they quite naturally brought the most curious and striking ones they could find So that if you talked even to a famous traveller about different kinds of animals, he would naturally think of hyenas, giraffes, hippopotami, tigers, gazelles, and so on and so forth. If you spoke of birds, he would think of ostriches and nightingales, and eagles and puffins: and it did not seem very difficult to imagine that these creatures were no particular relation to each other.

But during these months of travelling, Darwin had found that things did not work out quite like that. It began to appear to him that different kinds of creatures, both living and extinct, shaded off into one another. There were beasts that seemed to be *between* a sheep and a goat. There was a bird between a hawk and a buzzard, a beast between a wolf and a fox. But when he tried to divide up tropical beetles and tropical fish into sorts, Darwin nearly went mad! It surely couldn't be true that there were a hundred different sorts of beetle, each rather like our English stag-beetle? Or quantities of distinct kinds of barnacles? Then, again, what about those sixty-eight small dull-coloured beetles that he had found all in one day?

When he got to the Galapagos Islands, the puzzle became greater still. This bird which seemed to be between a buzzard and a hawk, lived there. Then there were some very odd finches: on these tiny islands there were six sorts of finches There were no toads or frogs, but there were hundreds of different sorts of lizard. He found no less than fifteen new kinds of sea-fish, and great big turtles, which could be found nowhere else. There were no mammals* except lots of mice, there were no insects except beetles, but fifty-five distinct kinds of bird, and a few snails.

* Mammals are creatures that give milk to their young They have fur or hair, not feathers or scales.

The *Beagle* came back by Australia and New Zealand, and here, as you can guess, there were plenty more strange birds, beasts, and insects for Darwin to see.

CHAPTER 3

When Charles Darwin landed in England on his return from the voyage of the *Beagle*, he was nearly twenty-eight. His father and brothers and sisters were very pleased to see him, and it was not long before he married a very nice girl named Emma and settled down in a house of his own.

But I have not mentioned one thing about the voyage. Darwin had had cases and cases of specimens sent back. Any ship he met that was going to England, he would get to take things back for him. There would be great packing-cases full of shells, others full of the skins of animals, others full of stuffed birds, others full of snakes and lizards in pickle, others full of pickled fish, others full of dried plants, and still others full of minerals

Then one of the first things he did was to have all these cases unpacked, and get other naturalists to come and help him arrange them.

Then, when this was done, for fifteen years he

worked and worked at trying to sort out in his own mind what all this meant. He wanted to try and make head and tail of all he had seen. By the time he had decided why there should be so many different kinds of beasts in the world, and whether each beast had been created separately or not, he had a family of big boys and girls of his own, for the job had taken him many years. You can imagine how long it all took him, from the fact that he worked for eight years on only one quite uninteresting kind of little sea creature, the barnacle. There is a story about this.

One of his children, born during that time, got the idea that this was quite a usual sort of thing, and that everybody's Daddy had this sort of work to do—so much so that when she heard of a Mr Smith who was said to ride out every morning, she looked very solemn and said: 'But *when* does Mr Smith do his barnacles?'

Darwin was often ill after he got home and had to work slowly. At last, at the end of nearly fifteen years, when he had quite made up his mind, but had not quite written his book, to tell the world why he thought that there were so many different creatures, a strange thing happened.

He heard that somebody else, a man named Alfred Russel Wallace, had had the same idea as himself. This was rather awful in a way. All his friends said. 'For Heaven's sake, publish what

you have written! Otherwise everybody will say you are only copying what Russel Wallace has said already.'

So, rather in a hurry at last, Darwin brought out his great book, *The Origin of Species*. It would not be any good, of course, to try to describe here all he had to say; so do remember, when you are reading this, that the next bit is not an account of how he proved what he had to say—that took him fifteen years—but only of his conclusions. What he believed was this:

That each kind of creature has not been created specially.

That all kinds of live creatures have become *adapted*, and have grown, through long, long ages of time, from very simple kinds of life.

That each beast in order to live has to eat, and to avoid being eaten; it has also, if it is to have children, to find someone of its own kind to mate with. From these three needs—(1) finding something to eat, (2) avoiding being eaten, and (3) finding a mate—have arisen the variety of animal forms we see now.

This is what Darwin called the 'Origin of Species'. All the wonderful variety of teeth and claws and hooves, and feathers and wings—peacocks' tails and fishes' fins, and so forth—have been developed by these needs.*

* There is more about this in my little book *How You Began*.

I think you will see that Darwin's theory did account, very much better than the idea that each kind of creature had been created specially, for the strange facts that Darwin had observed on his voyage. It accounted both for what the creatures he saw were like, and for their extraordinary variety.

It is quite interesting to go out into an English field and look at the plants and animals you will see there, with this idea of Darwin's in your mind. It is particularly interesting, I think, to see how different plants of the same family have found out ways of managing these three necessary things. Consider for a moment what you will be likely to find in an ordinary field.

There will very likely be buttercups. Now buttercups are so common (they manage so well) because they have attended particularly to the business of not being eaten. They have a juice which has a bitter taste and is poisonous: cows and sheep will not touch them because of the nasty taste. So buttercups have been able to grow and drop their seed everywhere: in the spring our fields are yellow with them.

In the hedge of the field there may very likely be some gorse bushes. Gorse is another plant that has, to use Darwin's word, 'adapted' itself in a clever way to avoid being eaten. Instead of

giving its juice a bitter taste and making it poisonous, gorse has grown prickles, and so it has survived.

Perhaps in the same field you will see certain live creatures as well as plants. Thrushes, of course, have wings, and are very clever at getting away from their enemies. That is their way of not being eaten. The charming voice of the male bird, as far as we can tell, has been developed to please the hen bird, who prefers to marry the cock with the best voice; and in this way the better-voiced cocks are always sure of getting a mate, and so they have the most children. You might expect, if this is true, that unless something goes wrong, birds' voices would slowly get better and better.*

Again, you might see two little timid creatures, one rather rare, one very common, both of which other creatures find very delicious to eat. Now these little creatures would need certain things if they were to go on living. A good idea would be for one of them to be very quick in running. One of them is a quick runner. Another thing that would be useful would be very sharp eyes or ears with which to see or hear its enemies coming. Another thing that would be excellent would be somewhere to hide. That is one way. The other way would be for a small beast to make itself

* Something very often *does* go wrong.

unpleasant to eat, and that is exactly what the other little beast has tried.

I wonder if you can guess their names? I am thinking of a rabbit and a hedgehog. Hedgehogs are not nearly so successful as rabbits. Too much armour never has been a very good device, either for knights or creatures.

Of course a great many other things come into the question. For instance, the rabbit's beautiful long ears would be no good to it, unless it had nerves that worked well and quickly, to carry the messages they collect back to the brain. Nor would rabbit, hedgehog, or bird, be able to survive unless they had thought out some way or ways of protecting their young while these were helpless.

Another thing which helps an animal to survive, is being able to live in a climate that other creatures do not like—for instance, in the Arctic, or in very dry places. Another kind of 'adaptation' is to be clever enough to learn to eat something that nobody else could get at before, or to live upon something that no other creature knew was good for food. Some naturalists say, in fact, that this is one of the most important of all, and that the real enemies of a grass-eating beast, such as the rabbit, or the gazelle, or the zebra, are not so much stoats, or foxes, or lions, as other warrens of rabbits or other herds of gazelles or zebras, that eat up all the food

CHAPTER 4

When Darwin published his book, *The Origin of Species*, most people who read it, or even only heard of it, were extremely shocked. It upset the ideas of naturalists and geologists. To ordinary people it seemed shocking, because it seemed to them to give less work to God in making different sorts of beast, and more work to a sort of strength and patience in the plants and creatures themselves. It worried Darwin very much that these people should be so shocked, as he was a peaceful, rather anxious man, and did not want to make enemies, but only to find out the truth, and get people to believe it when it had been found.

However, there was something worse in store for the people who were shocked. It was worse than even the idea that God had not made each kind of creature separately. The great English doctor, William Harvey, had been one of the first people to discover that a man's heart and the heart of a deer, or even of a snake, were very much alike. Well, that was the conclusion to which Darwin came about the whole of a man Darwin's ideas suggested that Man is just the wisest of the animals, and no more than that. Darwin's followers said that Man, too, had grown his wonderful brain, and his strong, delicate fingers, exactly as the lion has

grown its teeth and claws, the hedgehog its prickles, the thrush its sweet voice, and the peacock its tail. Perhaps Man was no more specially created than any of his cousins, the animals.

A great many people were furious, though some people made fun of his idea, and it was quite the thing to joke about 'your grandfather, the monkey.' Nowadays, as you may know, people do not think that we are exactly descended from monkeys, but rather that the monkeys, and we, are both descended from a queer little tree creature, probably a sort of lemur.

By the way, to this day some people still believe that Man was created specially, and is a kind of rather inferior angel, not a kind of very superior animal Personally, I like the idea of being an animal. I like to think that I am a relation of the creatures I am fond of—cats and dogs, and so on I like to think of Man as a kind of flower on the tree of life. I like to think that you who are reading, and I who am writing, are people of such old family that our ancestry goes right back and back to prehistoric monsters, and back beyond that to the smallest and simplest creatures of all, back to the time when the earth was first cool enough for the simplest single-celled creatures to float and drift in the tepid water.

PRACTICAL WORK

(Darwin was interested in all the things that have made earth out of rock, and mixed soil out of earth. So he studied glaciers, volcanoes, and torrents. But he also studied worms, and digging beetles, both for themselves and for the way in which they altered soils and earths He made one long experiment with worms. You might find it interesting to make a short one).

Make a wormery. Take a large jam-jar, put a little coarse sand or gravel at the bottom, so that the water drains away from the soil Fill up the jar with different layers of soil. You might put in first black earth, then chalk, then sand—all the colours that you can collect. Ram each layer fairly tight before you put in the next. The last layer should be dead leaves and garden mould. Now put in six or seven ordinary earth worms, and cover the jar with some glass or muslin to prevent the worms getting out. As you hope that some of the worms will make their homes down the side of the glass, cover the outside with black paper to make it dark except when you are looking. Sprinkle some water over the surface from time to time Worms will eat leaves, and root vegetables. Watch and see whether the worms bring any of the soil you put at the bottom up to the top.

Darwin's experiment lasted twenty-six years. Yours might last about a month.

STORY VII

LOUIS PASTEUR

(1822–1895)

CHAPTER I

THEY PUT UP ever so many statues to Pasteur in the end. On the pedestals of statues to soldiers and sailors they often, as you know, put little pictures of the chief battles in which the man took part, and of ships, or cannon, and flags. Well, when they put up a statue to Pasteur, what do you think they put round the bottom of it? Stars? Lightning? Microscopes? Not at all. They put a picture of a big flock of sheep on one side, silk-worms on another, and a thing like a beer vat on another. You will see why

Pasteur, like William the Conqueror, was the son of a tanner, and wanted to study from the time he was quite small; but he got so homesick when he went away to a boarding-school that his father had to bring him back. He studied crystals and made some valuable discoveries about how these odd things behave, and he did not have anything

to do with living things till he was quite grown up and had begun to teach.

The story of his discoveries about living things begins when Pasteur was a young professor of chemistry in the town of Lille in the North of France. After his lecture one day one of the boys said to him: 'Father is here, and would like to speak to you, Professor Pasteur.'

So the boy's father, Monsieur Bigo, came and told Pasteur that he made alcohol out of beetroots. This meant doing work something like that which goes on in a brewery. Now something had gone wrong with Monsieur Bigo's vats: the mashed-up beetroot would not ferment and go fizzy as it ought to, and his business was being ruined because his alcohol was turning out badly. It used to be good, but now it was the most awful stuff He seemed to do exactly the same thing every time, but sometimes his alcohol was so bad that it had to be thrown away. He didn't see how chemistry could help him out of the difficulty, but he knew that Monsieur Pasteur was a clever man. Would he help him? Pasteur decided that he would.

You know that something is put into bread to make it rise. You have heard that foam appears in the wine cask while it is turning from grape-juice into wine. You may have seen that beer is frothy. You know that milk goes sour and curdles. Well, people had known all that ever since the time of the

Greeks and Romans and ancient Egyptians, and possibly even before that ; but they did not know why these things happened.

Yeast is the stuff that is used to make beer froth, and bread rise. Leeuwenhoek realized, when he looked at it through his microscope, that the yeast was made up of little roundish globes, and that these globes seemed to be strung together like the beads of a little necklace.

Well, after examining Monsieur Bigo's beet-root pulp that refused to turn into alcohol, and after making a great many experiments, some of which turned out badly and some well, Pasteur came to the conclusion that the yeast was alive, and that it was only when the yeast globules were a nice round shape that Monsieur Bigo's alcohol came out all right. But sometimes a rod-shaped yeast grew in the vats instead, exactly as weeds will grow in a garden. These rod-shaped creatures produced quite a different effect, and it was when they were there that Monsieur Bigo's alcohol had to be thrown away.

All this was not absolutely newly found out by Pasteur, for a man called Schwann in Germany, and another Frenchman, had already said most of this ; but when they had said it they had been immediately contradicted by a famous scientist named Liebig 'Look at milk,' said Liebig. 'Almost exactly the same things happen to milk

as happen to wine and beer, but you don't have to put yeast into milk before it turns sour.'

Liebig said that what was happening to the beer and the milk when they went sour (either of themselves or from having yeast put in them) was just what happens to a custard made with an egg if you let it come to the boil, or to milk if you put lemon-juice into it. Nobody, of course, says that the lemon-juice is alive, or that the heat of boiling makes the egg or the milk alive. 'Very well,' said Liebig, 'it's just the same with milk or beer that ferments'

After a time Pasteur managed to cure Monsieur Bigo's alcohol, and it never went wrong again. Then he began examining milk very carefully, wondering if the two 'fermentations' were at all alike Under the microscope he saw that the yellowy-grey scum that clings to the sides of the jug when milk turns sour, was made up of tiny globules much smaller than those of the yeast of beer; it was much tinier than the mould that grows on old cheese or on boots that are put away in a damp cupboard, but of much the same sort. Pasteur took a tiny bit of the grey material and 'transplanted' it into clean milk, and found that it started souring the clean milk, too.

What was really happening was that he had 'bedded out' little yeast plants to new, good soil, and they had multiplied

He wrote about it in a scientific paper. 'My idea,' he said, 'is that the milk is simply food for the yeast plants.' In the making of beer or alcohol, he suggested, the yeast eats the sugar just as you eat your food, and throws out as waste the alcohol that people want.

Then there was one more question to be asked and answered. If these little yeasts are little lichens—little fungi—where do they come from? And when that question began to be asked, Pasteur found himself plunged into the middle of another battle fiercer than the one with Liebig It was one in which Leeuwenhoek had already taken part, but that had been more than a hundred years before and was all forgotten, so now the battle was begun all over again

The question was this. Do all living things come from seeds or eggs in which life already exists, or can life come from dead things?—or (if you like to put it in another way) do germs have parents, or do they not? People had believed quite decidedly that all creatures did not have to have parents. Aristotle said that every dry body becoming damp, and every damp body becoming dry, breeds animals. A man named Van Helmont even gave in a book an excellent recipe for producing mice. He said: 'You first take a jug or bucket and put into it some grains of wheat. Then into the mouth of the jug or bucket you squeeze some dirty linen.

In twenty-one days the wheat will have turned into mice. The mice will appear in a grown-up state and there will be both male and female mice.'

Learned people in Pasteur's day did not believe anything quite so silly as that (though some country people do to this day), but what they still believed was that small creatures like germs could come of themselves.

In 1859 a Monsieur Pouchet, Director of the Natural History Museum in Rouen, read a paper before the Academy of Sciences. In this he said: 'These people who do not believe in spontaneous generation* say that the germs of microscopic beings exist in the air, that the air wafts them about and carries them to a distance. Well, what will they say if I can show them that life will grow in artificial air that I have made in my laboratory, and which cannot have any germs already in it?'

Pouchet made a very elaborate experiment with hay-water. He had baked the hay, put it into a flask of boiled water sealed up, and plunged it upside-down in a basin of mercury. When the water in the flask had become cold, he opened the flask with tongs under the mercury, and then he let in some pure oxygen. A few days later he appeared before the Academy of Sciences with his flask. There

* Life coming of itself.

was no doubt that little patches of mould were growing on his hay. 'Where do these living things come from?' asked Pouchet. 'How can their presence be accounted for, except on the theory of spontaneous generation?'

The people who believed in spontaneous generation said it was nonsense to say that the air carries microbes about. Why, if all the germs that turn meat bad, and milk sour, and make crusts mouldy, were really present in the air, the air would be quite thick and foggy. You would have to imagine the air as solid as iron to hold so many germs

But Pasteur was perfectly sure in his own mind that germs *did* have parents. The difficulty was to prove it. He said that the reason why the mould had appeared in Pouchet's hay was that it had been pushed up into the flask from the surface of the mercury when the cork was taken out of the flask with tongs and when the oxygen was put in.

Then Pasteur made one of the prettiest and simplest experiments that have ever been tried. He took some broth which, in the ordinary way, goes bad exactly as milk or meat will. He put the broth in a flask Then he heated the glass and pulled out the neck of the flask until it was the shape of a swan's neck when the swan is just going to sip up a bill-full of water—only you must

imagine the swan's beak carried on further and pointing upwards The end of this long swan-neck was left open, and then (in its flask) the broth was boiled. The broth did not go bad.

'Easy to understand!' said the people who believed in Pouchet's theory 'You have spoilt the broth by boiling it so hard. It will never go bad now.'

'Well,' said Pasteur, 'we will see.'

Then he took his flask and let a little of the broth run into the bend of the neck of the bottle: there the little drop of broth soon began to grow mouldy and turn sour.

What had happened was this. As you probably know, germs and yeasts and mould are carried by the dust in the air, and this dust had not been able to find its way up that long swan-neck. All the dust and the germs had got caught in the bend. The bend was a germ-trap. Directly the broth got there the yeasts and mould began to grow in it, and it went sour and grew mouldy, exactly as Pasteur had said it would.

As a matter of fact some of these swan-neck flasks containing broth are still kept in a museum in France.* These are the actual flasks of broth got ready by Pasteur: their labels are now yellow with age, but the broth in them is still as clear and

* L'Institut Pasteur

free from mould as on the day when Pasteur boiled it.*

But there was still one point that Pouchet had made. Pouchet had said, if you remember: 'If this is really true about germs being in the air, the air must be so thick that it would be quite foggy and impossible to breathe.'

Now Pasteur had a theory that air differed very much as to the amount of yeast and mould that it contained, and this is the experiment that he tried to prove his point.

He packed up a lot—about seventy—of his swan-neck flasks with broth in them, and went by train to the Jura Mountains, and stayed in a little hotel. In his bedroom he broke the necks off half a dozen flasks, and then, after a few minutes, sealed the flasks up again. Next morning he walked into the fields and there, far away from any houses, he broke off the necks of half a dozen more flasks and sealed them up again Then finally, he went on by train again. This time he went to the Alps, and went with a guide up a high mountain called the Montanvert. Here, high on a famous glacier, called the Mer de Glace, he broke off the necks

* By the way, the real reason why Pouchet's hay got mouldy was not quite what Pasteur thought Pasteur always used boiled yeast 'soup' or ordinary broth to make his experiments with Now hay contains germs that are much harder to kill than ordinary yeasts, and though neither Pouchet nor Pasteur knew it, Pouchet had not really done enough baking and boiling to kill what was in his hay already This was proved by more experiments much later on

of some more flasks. These he also sealed up again.

When he examined them all some time later this is what he found: The flasks opened in his stuffy hotel bedroom contained utterly mouldy broth. The flasks opened out in the fields were not nearly so fine a garden of yeasts and moulds. The flasks opened up on the glacier had no germs in them at all. The broth was clear and was neither sour nor mouldy *

During most of the time in which Pasteur was making his experiments, he had miserable places to work in. He never had anyone to help him He was a very hasty man, too—not at all like Darwin, who could wait fifteen years before he published anything about what he had found out However, fortunately Pasteur had a very nice wife called Marie, the daughter of a professor in one of the universities where he had taught Madame Pasteur was splendid at consoling him, and helping him when he was too poor to buy the things he needed for his laboratory, or had to sit up half the night clearing up, or when people said he had done his experiments all wrong. Madame Pasteur always had hot meals ready for him, and treated

* There is a splendid account of this experiment, explaining how much more difficult it all was than it sounds here This account is in a book on Pasteur by Grace T Hallock and C E Turner in a series called *Health Heroes* You should try to get it if Pasteur interests you There is twice as much in it as I have space to tell It was written for children and is full of pictures Ask at your Public Library

him extremely well and believed in him; but they had a worrying time with their family. Several of their children died, one of typhoid and one of another infectious illness.

CHAPTER 2

One day an old professor, who had taught him when he was a young man, told Pasteur that the silk-worms were sick. You must know that in the South of France, where Pasteur had lived when he was a little boy, silk-worms are very important. The most beautiful silks in the world are spun and woven in Lyons, and there are big silk-worm farms all round that part of the world, with groves and orchards of mulberry-trees on whose leaves the silk-worms feed.

The news that the old professor brought to Pasteur was that nearly all the silk-worms round Lyons were dead or dying. They got black spots on them, as if someone had peppered them. Then they grew weak and died, instead of spinning their silk cocoons. The country of mulberry-trees that used to be rich and gay was desolate now, and the people were nearly starving. Pasteur had helped M Bigo, and had proved that wine and beer were made with the aid of certain tiny helpers and

servers, so couldn't he come and find out what disease it was that was killing the silk-worms?

'But I have never even seen a silk-worm,' said Pasteur. 'How can I be a silk-worm doctor?'

But the old professor begged and begged him. It was some disease that had killed the worms: nobody could find out what it was. Then he told Pasteur once again how the silk-worms all came out in little black spots that looked like pepper.

Pasteur went, and took his wife and all the children and the microscope and three young assistants with him. The silk-worm farmers laughed at the thought of a doctor who had to be told so much: why, he scarcely knew that a silk-worm was really a caterpillar, spun a cocoon round itself, turned into a chrysalis inside the cocoon, that the chrysalis turned into a moth, that the moth climbed out and laid eggs! But now, as soon as the eggs hatched out into worms the worms got these spots and died

Pasteur had a lot of dead silk-worms brought him, and some of the few healthy ones that could still be found He cut them open, and looked at their insides through a microscope. The unhealthy ones had black spots outside, and wee little globules inside. The healthy ones had no globules Pasteur felt sure that the globules were a sign of the disease; and he told the farmers that if they would examine the father and mother moths after the mothers had laid, and see to it that only

the eggs of healthy moths were allowed to hatch, then they would get healthy worms next season.

Well, it was very difficult to make the farmers use a microscope—in fact, they said they couldn't. Pasteur said 'Nonsense,' and told them how his little girl who was only eight could handle his microscope and see the little globules. So a whole lot of the farmers clubbed together, and in different towns they bought microscopes and did as Pasteur told them.

He went all round big districts like that, travelling every day, showing people how to use microscopes, making speeches and explaining to the farmers what they must do.

And what do you think happened? The next spring, when it was time for the worms to hatch out of the eggs and spin their silk cocoons, miserable, unhealthy worms hatched out of the eggs that had been so carefully chosen! Pasteur had been wrong. There were worms that shrivelled up and died, there were worms that would not eat, there were worms that could not hang on to the twigs of the mulberry-trees.

Poor Pasteur! Everybody was angry with him. The farmers had gone to so much trouble and expense, and he too had hoped that everything would be all right. Now, after all, he had been quite wrong. They were not only angry, they also laughed at him.

He began examining silk-worms again. He tried all sorts of experiments. Worms ill with the pepper-disease died in about three weeks. But now he was getting worms that died in about two days; and some of them had the little globules in them, and some hadn't. Poor Pasteur was all mixed up.

But at last after months and months of experimenting, Pasteur and his assistants found that it really *was* the little globules. The globules were alive, and they were parasites. They were what made the worms sick. The mistake had been that Pasteur had taught them the wrong way to look for the globules in the bodies of the father and mother moths. So in the end the microscopes were not wasted, nor the time of the farmers who had learnt to use them.

Once more Pasteur went round everywhere, and showed the farmers the new things he had found out. He told them that they must keep their healthy worms away from all contact with leaves where sick worms had crawled. He worked very hard, sure that this time things were going to be all right. But now he himself got suddenly ill, and nearly died. He had what is called a stroke and was so ill that he was paralysed on one side ever afterwards; but, ill as he was, he could scarcely stay in bed any time at all.

He really had been right this time, and that year the farmers had a proper silk harvest.

For six more years Pasteur worked at the silk-worms, and taught the farmers how to fight, not only the pepper-disease, but also a disease that killed in two days, and lots of other things that made silk-worms less big and less healthy than they ought to be.

CHAPTER 3

Now, at this time there were a lot of other people hunting microbes, besides Pasteur. Robert Koch, a German, had discovered that it was microbes that gave scarlet fever and consumption. Not that all the doctors believed him—far from it. A lot of the doctors behaved just like the old professors who wouldn't look through Galileo's telescope.

One of the things Koch had been finding out about, was a disease called anthrax, which kills sheep and cows. Sometimes poor farmers were ruined by having a whole flock of sheep die, or perhaps it would be just a few lambs. It was a queer disease: though nobody knew where it came from, they were pretty sure it was catching, but they were not *quite* sure.

Koch wanted to find out all about it; but he could not keep cows and sheep in his laboratory, and small animals did not seem to catch it.

But at last he found that mice caught it, and by

means of mice suffering from anthrax, Koch was able to study the disease. He found that when an animal had anthrax, its blood turned almost black because it had heaps and heaps of tiny dark rods floating about in it. As the animal got worse, the rods began to grow: there would be two where one had been before. Then the rods seemed to get longer and longer, and stretched out into endless dark tangled threads. They seemed to push their way like snakes, and in two or three hours the drop of blood, or the little piece of inside which Koch was looking at under his microscope, would be hidden by the myriads of threads

Koch made sure that these rods were alive, and that it was because they grew in millions inside the mice and the sheep and the cows that these creatures died.

Pasteur got to hear about Koch's investigation of anthrax, for a very great many sheep and cows died of this disease in France as well as in Germany. Not all animals died when they got anthrax, so how did animals conquer the long black thread germs? If anthrax was caused by germs, Pasteur thought, could there be any sort of *good* germ that would eat the bad germs? He began to try growing anthrax germs in animals in his laboratory, and studied the changes that went on day by day both in the ones that died and those that got better.

Then Pasteur heard of a 'vet'* named Louvrier, who was said to have cured hundreds of cows who were dying of anthrax. The farmers were very pleased, and said that some scientist ought to come down and see this marvellous cure. So Pasteur went.

And what do you think he found Louvrier was doing? First, he got several of the farm workers to rub the sick cow violently to make her as hot as they could. Then long gashes were cut in the poor cow's skin. Turpentine was poured into the cuts, and finally the poor miserable, bellowing cow was smeared all over with a thick layer of most horrible ointment soaked in hot vinegar. Then the poor creature was covered over with a cloth which was sewn around her.

Pasteur was very polite, but he didn't think much of this way of curing cows, and he said to Louvrier that of course some cows did get better of anthrax anyhow, and was Louvrier quite sure that it was his cure that made them better?

So they tried an experiment. Pasteur got a big syringe with a hollow needle at the end, and he filled the syringe with a sort of broth in which heaps and heaps of live anthrax germs were floating. Then he pricked the shoulders of four healthy cows, pushed in the needles, and squirted in the broth so that the anthrax germs went floating away

* Veterinary Surgeon or animal doctor.

in the cows' veins. The next day anyone could see that the cows were beginning to get ill: they had swellings on their shoulders, and their breath came in snorts.

Then Louvrier chose two of the cows, and to these he gave his treatment. But to the two other cows no treatment was given at all. So two of these poor cows were rubbed and had gashes cut in them, and had turpentine poured on them and were covered with vinegar ointment, and were sewed up in sacks. But two of them were just taken back to their cow-shed.

In two or three days Pasteur and Louvrier came to see the cows, and what do you think had happened? One of the two cows that had been sewn up in sacks got better, and the other died. One of the two cows that had had nothing at all done to it had got better, and the other died. Just one of each.

After that Pasteur felt much more sure that Louvrier's treatment was no use. But all the same he learned something from the experiment.

I told you that two of the cows got better, didn't I? They had had anthrax, and they had got better from it. One day Pasteur went and looked at them in their cow-house: they were quite happy, and had begun to eat again. Pasteur began to wonder whether cows could have anthrax twice. He wasn't sure.

So he gave each of the cows that had got better another big dose of very active, lively anthrax germs. And then he waited. Nothing happened to the cows at all—there wasn't even a tiny swelling at the places where he had pricked them !

Then Pasteur thought : ' Now I know something. A cow can't have anthrax twice. There must be something in the blood of a cow that has once had the illness that kills the germs.'

Then an idea came to him : ' Couldn't we make cows and sheep just a little ill with anthrax, hardly at all, and then they would be safe from this terrible disease ? '

Then he worked and worked, and he tried all kinds of experiments, sometimes not with anthrax germs and sheep and cows at all, but with chickens and quite different germs. And he came to the conclusion that if you kept these germs for a long time in a bottle, they did not die, but they got weak, and that if you put old, weak, anthrax germs into the veins of sheep and cows, they would be a little, but not very, ill. Once they had been a little ill with the anthrax, they would never die of it.

And then he thought and he thought. After all, something very similar had been done by William Jenner, the man who brought in vaccination for smallpox.* He wondered whether if something of

* Vaccination for smallpox is not exactly the same as the inoculation Pasteur was experimenting with, but it would be too long to explain the difference here.

the sort was true about both anthrax and smallpox, it might not also be true about some other diseases. If it was, then a fine way had been found of saving living things from germs, and indeed, of saving man and beast from death.

Pasteur was about fifty-eight now, when he got the idea about the weak germs. It was such a wonderful idea, that men and animals could be saved from death, that Pasteur and his two chief helpers worked and worked at preparing their broths of weakened germs. It was a very ticklish job, for, as you can guess, it was so easy to give people or animals just too many germs, or ones that were livelier than you thought, and kill them. Or, on the other hand, you might give just too little, or dead germs, and not protect them.

Some of the other professors said that Pasteur was doing a very dangerous thing.

All the learned men were very much excited about the new vaccines, as the weakened germs were called, and some of the other professors, who had not thought of the idea, were angry. Ordinary people did not know what to believe, so then someone said: 'Pasteur says that it is quite easy to make vaccine that will protect sheep and cows from anthrax. How splendid if that is true! It will be a very good thing for French farmers. Let Pasteur prove that he can do it. We will have a grand public experiment. If he is

right, the farmers will be the gainers: if he is wrong, Pasteur must stop boasting about his great discoveries.'

So the people who wanted to try the experiment bought forty-eight sheep and two goats and four cows Pasteur said he was willing to try. He had already tried experiments on a few sheep that he had bought himself, and had been quite successful in making them safe against anthrax.

So now the fifty-four animals were divided into two lots of twenty-four sheep, one goat, and two cows each. One lot were to have doses of weak germs to protect them, one lot were to be let alone. Then on an appointed day Pasteur was going to inject all the animals with the most deadly and terrible anthrax germs that he could grow in his laboratory. The animals that he had protected beforehand would be perfectly all right, he said: the others would all die in two or three days. His two chief helpers, Roux and Chamberland, were not very happy about the test—they reminded him how delicate the work was, how difficult it was to get the doses just right. They knew fairly well about sheep and cows, but how much should a goat be given? Pasteur told them not to fuss.

So the great experiment was tried. Pasteur and his assistants took their bottles and syringes and got into the train. They came to the field and the sheds where the sheep and the cows and goats were.

Pasteur walked in first and bowed to the crowd which was waiting to see him. There were all sorts of scientists and ministers of State and grand people there: some of them cheered, some of them looked very disagreeable. There were a lot of newspaper reporters there, too, including one from the London *Times*.

I wonder if the assistants thought that perhaps someone might have played a trick on Pasteur and that all the sheep mightn't be healthy? However, it was no good worrying.

All the forty-eight sheep, the two goats, and the four cows were to be given anthrax germs. Pasteur stood up in front of everybody and said: 'Now you will see. The ones that have been protected beforehand with the weakened germs will not die—the ones that have not been protected will surely die.'

But though he spoke bravely he was very nervous. All the animals had the anthrax germs put into their veins. Then the two days' wait began.

At last the third day came when people would once more come and judge whether Pasteur had been right or wrong. By two o'clock a great crowd had gathered round the sheds; the newspaper reporters came ready to telegraph the news all round the world, the scientists and ministers were there. Pasteur and his assistants

marched up and looked into the sheds. And this is what they found :

Not one of the twenty-four protected sheep was dead, nor the goat, nor the two cows : they weren't even ill ! They had all had a deadly dose of germs, but the dose of weakened germs they had had protected them, just as Pasteur had said it would. They ate and frisked about and had never been better in their lives.

And now what about the unprotected beasts ? If Pasteur was right all of them ought to be dead or dying. And so they were. Twenty-two out of the twenty-four sheep were dead, and the last two were staggering about almost dead ; the goat and the two cows were dead or dying. Nobody could doubt any longer that Pasteur had been right.

How the crowd cheered him ! The very people who had been least willing to believe in him and his wonderful microbes rushed up and shook him by the hand. The newspaper men rushed off to the telegraph offices, and to London, and Berlin, and Rome, and Moscow, and New York, the telegraphs clicked out . ' Pasteur's experiment is perfect.'

France went wild with enthusiasm. Everywhere farmers and animal doctors sent telegrams begging Pasteur for thousands and thousands of doses of the life-saving vaccine of weakened germs. And Pasteur turned his little laboratory—he had never had enough money to make a fine one—into

a sort of factory, and they sent out quarts and quarts of vaccine

But though Pasteur was famous, there were still plenty of people to make fun of him and to hinder him if they could People made jokes about microbes in the newspapers 'Will you have some microbe?' was considered a funny remark to make to anyone. 'To-day microbes are the fashion,' said one of the papers, 'but they must not be talked about, once the learned M Pasteur has pronounced the sacred words, "I have spoken"'

However, the French Government soon offered Pasteur the Grand Cross of the Legion of Honour (the highest honour in France), and the Cross to Chamberland and Roux, the two young men who had helped him so much and worked so hard.

They were all very pleased when the news came of the honour that had been done them. Madame Pasteur described the scene, and said that they shook hands all round, and kissed each other, all among the experimental mice and guinea-pigs

In August, 1881, Pasteur came to a big Congress of doctors in London. When he arrived in the hall, it was full to overflowing. Pasteur was told that he must not sit at the back—he must come and take his place on the platform. As he walked down the hall there was an outburst of applause. Pasteur looked round, thinking that some royal personage must have arrived, and was amazed when the

President of the Congress told him that it was not a royal personage, but he himself, Pasteur, who was being cheered.

It was not long after this that he was elected to the French Academy. This is a body of only forty members—poets, critics, astronomers, doctors, all sorts of learned men ; and to this day it is a very great honour to be elected to it. They are called the Forty Immortals.

After this Pasteur made many more experiments. One experiment resulted in the prevention of swine fever. Last of all he tried to find a cure for dog-madness. The reason why he chose to fight this particular disease is thought to have been something that happened when he was a little boy. This is the story :

One day when Louis Pasteur was coming back from school, he saw a crowd gathered round the blacksmith's shop. He could hear the sound of the bellows being blown in the usual way, but there was something very unusual about the crowd. People seemed very much worried. A woman gave a shriek. Then Louis managed to push his way in between the people's legs, and he saw a sight that he never forgot. Six or seven neighbours were holding down a half-dressed man, and the blacksmith was pressing a red-hot iron into wounds on his hand, arm, and leg.

It was only afterwards that Louis found out the

reason for the commotion. A farmer had been bitten by a mad dog, and the one chance of saving his life was to have his wounds cleansed by the heat of a red-hot iron as quickly as possible after he had been bitten. Pasteur hated to see pain, and he never forgot this terrible sight. When he was old and famous he turned his mind towards the possibility of curing this disease, which is called rabies or hydrophobia.

He had a very difficult time of it, and some people say that, in the end, he stumbled on success quite by chance. People were quite doubtful about the whole thing in those days ; but a band of doctors was sent from England (one of them was Lister, of whom you will hear more in the next chapter) to find out as much as they could about the treatment. Pasteur helped them in every way he could, and at the end of more than a year of further experimenting they agreed that a cure had really been found.

At last a great building was put up in Paris—the Institut Pasteur ; and proudly he used to go every day to watch the work. But he was getting old. Most of the best of his work had been done under the difficulty of his health being very weak, but he did not care now, for he knew that his work would go on whether he lived or died. There was Lister, who had applied what he had discovered to surgery ; and there were other scientists all over

the world who would go on with what he had begun.

Pasteur knew very well that it would be a long time before all disease was conquered—that has not happened yet ; but he had done his share of the work, and done it nobly.

On his seventieth birthday the great hall of the Sorbonne was filled with all the most distinguished scientists of France and foreign countries : the top gallery was crowded with eager schoolboys. The President of the French Republic and all the ministers were there. The great Lister came forward to meet Pasteur, saying : ' You have raised the veil which for centuries has covered the origin of infectious diseases. You have discovered, and proved, that they are caused by germs.' From far and near, from all the great cities of Europe, from learned societies and from schools and universities, came every sort of birthday gift.

Pasteur was old and tired, and his voice was very weak, so his son read out what he wanted to say. Pasteur wanted to tell them that he was a man who truly believed that peace and science would one day triumph over the ignorance of war, that the nations would come together, as they had done that day—not to destroy, but to build. ' The future,' his son read out, ' will belong to those who have done the most for suffering humanity.'

Then he said he wanted to speak to the young

people up in the gallery. He told them that they ought to ask themselves: 'What have I done in return for my education?' And then, 'What have I done for my country?'

'Ask that, till the moment comes when you have the immense happiness of thinking that you have contributed something to the progress and welfare of humanity.'

When Pasteur was seventy-five he died.

EXPERIMENT

Get a pennyworth of live yeast from the baker's Put a tiny bit of it into a saucer of sugar and warm water, another bit into a saucer without any water, and a fairly large bit into a tightly corked bottle half full of sugar and water to which you have added a little ginger essence Keep warm and examine in 24 hours Taste each of the mixtures

STORY VIII

LORD LISTER

(1827–1912)

CHAPTER I

IN THE DAYS when Joseph Lister was born, London did not spread nearly so far as it does now. His father's house was near Epping Forest, and very few people went there to picnic. The house had a big lawn with cedars on it, and a good many curious foreign shrubs.

The Listers were Quakers—members, that is to say, of the Society of Friends. Joseph had to go to the Quaker church, 'meeting' as it was called, with his parents, twice on Sundays and once on Thursdays. To these same meetings used to go Elizabeth Fry. She was a Quaker too, and was doing very interesting work then, trying to make prisons better. In those days poor prisoners got no beds or bed-clothes, and were not properly fed, while, if they were ill, no one bothered about them or nursed them.

The Listers were quiet, gentle people, and like

Quakers thought it wrong to go to theatres, ıce, or hunt, nor would they play any kind of :al instrument. The men of the family wore black, grey, or drab suits, the coat with a us stick-up collar, and a white necktie. Their had broader brims than were the fashion. ıh's mother wore the same sort of dress as all ther Quaker women. It was a plain drab dress wide skirts, a very clean, crisp muslin hand-ıief round the neck, a little shawl on the lders, and a very becoming plain white muslin

ıakers never called each other 'Mr' or 'Mrs' always 'Friend'—'Friend Fry,' 'Friend er,' 'Friend Gurney.'

ıt the Listers were not dismal people at all. y used to ride, and play cricket and football bowls; they skated in the winter, and had e jolly parties with their neighbours. Joseph's er, although for most of his time he worked at ısiness in the City, was very fond of making roscopes. Like Leeuwenhoek, he used to grind lenses himself. Joseph and his father were r fond of each other.

ɔseph went to a day-school, where, though they to learn a great deal of Latin, the boys were taught mathematics, natural history, and dern languages. This was much better than win's school in Shrewsbury, where, as you

may remember, hardly anything but Latin and Greek was taught. It was not very long before some of the school essays that Lister was writing were about such things as how the skeleton of a man or a frog is put together, or about the structure of bones. He wrote one called *The Similarity of Structure Between the Monkey and Man.* This one Lister wrote when he was fifteen or sixteen years old.

Just before he left school he was allowed to give the other boys a lecture on chemistry. Joseph often used to practise cutting up fish and small animals. He would get the meat off by soaking, and put their skeletons together again. He wrote to his father :

'When Mama was out, I was by myself and had nothing to do but draw skeletons, so I finished the cranium and named the bones of it, and also drew and painted the bones of the front and back of the hand and named them. Mama came home on seventh day* at about two-o'clock, and in the evening, with John's help, I managed to put up a whole skeleton, that of a frog, and it looks just as if it was going to take a leap ; and I stole one of Mary's pieces of wood out of one of the drawers of the cabinet in the museum, to stick it down upon, and put it on the top of the cabinet with a small bell-glass over it, and it looks rather nice. Don't tell Mary about the wood.'

* The Quaker name for Saturday.

But long before that time, he had said that when he was grown up he meant to be a surgeon. It was entirely his own idea. However, none of his family objected, and so a surgeon he became, and, as you will hear, one of the greatest surgeons who have ever lived.

CHAPTER 2

Now we will skip to the time when Lister had become a young surgeon. Will you imagine that it is the year 1848. Please think that you are in a long room. All down the room there are beds. On the pillows you see heads. It is rather hot, for the windows are tight shut, and there is a roaring stove in the middle of the room. Some elderly women are standing about at the far end of the room: they wear black dresses, and some of them are putting screens round a bed.

You yourself are one of a group of about four young men, you are dressed in a black frock-coat and a high white collar, and a rather nice, serious-looking young man, dressed in much the same way, is taking you round and explaining things to you. Who are you and where are you?

Of course you might have guessed directly that you were in a hospital ward, and that you were a medical student, if I had told you that you had on a white coat, and if I had said that the young man

who was taking you round also had on a white coat Then you might have expected to see shiny white fixed basins with glittering taps at one end of the long room, and a trolley with glass boxes on it full of lint and bandages.

But then, if I had told you to see all that, and to feel fresh cold air, and smell a slight smell of new-scrubbed wood, and disinfectant, you would have been in a modern hospital ward, and not in one of the year 1848. For in those days the windows were kept shut, and the wards were often terribly stuffy. Neither the nurses nor the doctors wore washing clothes. The surgeons did not wash their hands at all—except, I suppose, when they went home to dinner. When they attended to the patients' wounds they used the same probe, basin, and sponge, and went on from one patient to another.

The young man who is taking you round is Lister of course, whom you used to know as a boy. He looks rather sad. Things are not going on very well in University College Hospital. He is telling you about some of the cases. It is a surgical ward, where people who have had accidents are brought in, or where people who have just had operations are put to get better. But now, for more than a week it has not been possible to do any operations in the one where you are, because there has been so much of the terrible hospital gangrene and blood-poisoning about; and if even part of

somebody's little finger should have to be cut off, it might be dangerous. A very dangerous state of things might result from the simplest wound because of these two illnesses, or from erysipelas (St Anthony's Fire). In all these troubles the sick person would get restless, thirsty, and flushed, and begin to toss about in bed. His temperature would go up, and he would have shivering fits.

Sometimes a man would come in who had been run over. The surgeon would lay the leg along a splint, so that the two ends of the bone touched. He would wash the wound out, and hope it would heal up. Then, just as the bones had begun to grow together again and the patient to get better, one of these horrible, disappointing diseases would begin. The patient would get feverish, the leg would be terribly swollen and painful, and if it was hospital gangrene it would go black and have to be cut off. Sometimes when a wound went wrong in this way, they would try cutting it off a little higher up; then *that* wound would go wrong, and so on until the patient died.

If a person swallowed a halfpenny or a key or something of that kind, the surgeons would not operate to take it out while these sicknesses were about, for though the operation was simple enough, and the surgeons were both kind and skilful, they dared not do it because the wound would be so likely to go wrong. A man would have a better

chance with a whole skin, even if he had got a halfpenny inside him.

Lister by this time had become a very brilliant young surgeon. But he was getting very miserable about the state of things. What, he thought, was the good of his or any other surgeon's performing brilliant operations, and sewing up wounds quite beautifully, when soon afterwards the carefully dressed wound would have become a sore, and the sore an agonizing red, angry boil, and in the end the patient would either die, or at best, the painful wound would take so long to heal and become so stiff, that the patient would be crippled for the rest of his life?

CHAPTER 3

Time went on, and Lister left University College Hospital and went to Edinburgh, and then to Glasgow. Things were just as bad there: the surgeons and doctors were kind, but woe betide the patient who had a wound, for anyone in hospital with a wound, however small, was very liable to die of it.

Except one sort of wound! Lister began to notice something very interesting and odd. Among all the sick people he had seen, there had been one or two who had had a rib, or several ribs, broken, without their skin being damaged at all. When a

rib breaks, the sharp broken end very often gets crushed inward. Then it sticks into the lung and wounds it, sometimes quite badly. Here was a wound, here was bleeding, yet in these cases, Lister noticed, no sore ever formed. The patient did not get feverish, the place did not begin to swell; nobody ever died of the dreadful gangrene or blood-poisoning.

But Lister noticed, if, besides the wound inside where the broken rib stuck into the lung, there was also a wound through the skin, then that wound through the skin usually went wrong just like all the others.

Lister puzzled over this for a long time. He set himself a task. He determined to see if some method could not be found by which an open wound could be made to behave like a closed one. He studied what other doctors were doing in other countries—France, Italy, Germany, and America. The date by now was 1860 or so.

Does the word 'France' make you think of anything?

If you noticed, in the last story, it was just about 1860 that Pasteur in France was publishing the results of his studies of yeast. Pasteur had proved by his beautiful experiments with the swan-necked flasks that bacteria—germs—are carried by the dust in the air. Pasteur had just proved that beer froths and bread rises, because yeasts—tiny

living things—have been growing in the beer and the bread. He proved also that it is the growth of other exceedingly small living things that makes milk and meat go bad. The experiments of Schwann in Berlin and of other scientists showed very much the same results.

Lister was teaching younger surgeons by now, and he used to repeat with them Pasteur's experiments with the swan-necked bottles, so that they could prove it for themselves. Then, after having studied everything that other people could tell him, Lister took the next step. Quite independently he came to the conclusion that when a wound went wrong, exactly the same thing was happening as when beer fermented or milk went sour. The wound went wrong only because bacteria got into it. If the skin was broken or cut, either by accident or by the surgeon, germs very like the yeasts, but giving rise to blood-poisoning, erysipelas, or the terrible hospital gangrene, got in at the unprotected place and grew and multiplied there. The fevers, swellings, and so on, which always came with the diseases, were the result of the irritation caused by the growth of these tiny living creatures. If living bacteria could not get in, then there was no trouble. A wound was chiefly dangerous because it was a door through which the germs could get in.

So far Lister's new theory is exactly what is believed by doctors all over the world to-day.

But then Lister went on. He said that bacteria were carried in the air, and that it was clearly impossible to keep all air out of a wound all the time, especially in the case of an accident. A surgeon could always be sure that, at some time or other, air, and therefore germs, would have got into the wound. Therefore Lister argued that in order to make an open wound behave like a closed one the germs which must already be in the wound must be killed.

If you have ever had an infectious illness in your house, or had to go to the fever hospital, you will remember that the mattress and bedding on which the ill person slept, had to be sent to be baked, that the sheets were boiled in the copper at home, and that very likely all the books and toys that the sick person used, were burnt. But you cannot bake, or boil, or burn, people. How, then, are you going to destroy the germs in their wounds? This was the first practical difficulty.

Lister thought of a way. It was to use disinfectants. The only thing he could get in the way of a disinfectant, at that time, was a very crude, oily kind of carbolic. He tried making it cleaner, and when he had refined it a bit he began to put his new theories to the test. The carbolic would be quite harmless in any case, he thought, so he was not afraid of hurting his patients by trying something new on them.

He tried his new method on five or six sick people. There was a little boy of ten whose right arm was badly broken, the skin was terribly torn and hanging loose in strips. Then there was Charlie, who was only seven. He had been knocked down by a bus, and his right leg had been broken. He was nearly dead when he was brought in—too ill to have his leg cut off, which would have been the usual thing to do. Then there was a man with a terribly badly broken leg with a huge wound; and a boy of about eleven, who had also been run over. All these people were dangerously ill, and their chances weren't considered good.

Lister himself dressed all the wounds of his test cases, and this is what he did. He soaked a piece of rag in strong carbolic and laid it on the wound. Then he bandaged the arm or leg on to a splint in the usual way to keep it steady. Then he covered the wound again with more carbolic rag; and over this he put a piece of tin moulded to the right shape. This was to keep the carbolic from drying up. To his joy all these people got better. They had been very near death, all of them, and would not have been strong enough to get over even a mild attack of blood-poisoning. But they did not have to try. For their wounds healed quietly and steadily. They did not get feverish, there was no swelling. The bones joined up, the scars were small.

Meanwhile in the other wards of the hospital the usual thing was going on, arms and legs were having to be cut off, sores were developing round the wounds, temperatures were going up and patients were dying.

The other surgeons went on operating in the same sort of old operating room too. Imagine a small room, none too clean, with a dusty skylight. There would be one tin jug and basin, and two or three ordinary sponges. The surgeon would be wearing the dirtiest old coat he could find (for what was the good of making a clean coat all messy?) The more grubby his operating coat the prouder was he, for it showed what an experienced surgeon he was. The nurse would be in fusty black, and she would only wash up the things right at the end when all the operations were over.

CHAPTER 4

By the time he wrote his first articles about it, and his new method became known, Lister had treated eleven cases, some of grown-ups and some of children, all successfully.

I don't believe you'll be the least bit surprised to hear that for a long time nobody believed Lister. They said that these eleven people had just

happened to get well. People *did* get well sometimes—even in the bad old days.

Lister came back to London to teach the surgeons there his new method; but they didn't want to learn. For years nobody bothered about him; they let him go his own way. The days of persecuting people for that sort of discovery were past by then. Lister was welcome to try what methods he liked, but his 'antiseptic' system was laughed at.

Lister's operating room was quite different from the ordinary. Lister took off his coat and put on a white one. Lister washed his hands very carefully two or three times. Lister kept all his instruments in carbolic, and he even had a spray of carbolic going over the wound all the time while he was operating, to be sure that no germs could get in. The difference was that the people that Lister had operated on got well.

Well, the time came when the other surgeons had to give in and admit that Lister had been right, and that he had absolutely changed surgery. If a man had swallowed a halfpenny, or had something wrong with his ear, or his eye, or his inside, it was now quite safe to cut him open and set the matter to rights, for wounds made by the surgeon were sure to heal. They were cleanly made and they stayed clean.

At last everybody honoured Lister, and hospitals

everywhere followed what was called the Listerian method. The lives of millions and millions of sick people were saved, when all over England, all over America, all over Germany, France, Italy —in fact, the whole world—the hospitals were changed and Lister's 'antiseptic' method was adopted.

Then there was the grand day which was described in the last chapter, when Pasteur and Lister met at the Sorbonne amid a cheering crowd of doctors and scientists, who all did honour to the two great men—Pasteur the man who had proved what bacteria were, and what they did, Lister who had taken Pasteur's discovery and used it for healing hurt flesh. It was a great day and both men deserved the honour they got.

I said a few pages back that 'so far' all doctors agree with Lister, meaning that now better ways have been found than Lister worked out. Lister's method was called the 'antiseptic method,' but even in his lifetime what is called the 'aseptic method' had begun to be used.* For two points had really been missed by Lister. They were these:

1. All germs are not bad for wounds.

2. What will hurt a germ will also hurt the growing tissues which are trying to close up the wound.

* These words mean 'against germ' and 'no germ.'

Surgeons don't make war on all germs now, but only on the bad ones, and they do not put strong disinfectant on wounds they have made, because disinfectants make healing slower.

Instead, then, of the carbolic pads and spray that Lister used, surgeons now rely on the most extraordinary cleanliness. Instead of trying to kill germs with carbolic, they try not to have any harmful germs about. The fuss and worry which this means for the doctors and nurses is extraordinary. In a modern operating theatre there is such a scrubbing, and a rubbing, and a putting on of overalls and washing of hands, and steam-heating of dressings, and sterilization of this, that, and the other, as is hard to believe. But all the fuss is well worth while, for now nobody dies of hospital gangrene or blood-poisoning, and the most delicate 'mends' can be done inside the stomach, or chest, or head, without any danger of the vital parts of the body being hurt by any of the dreadful diseases of the old days.

By the way, *asepsis* can only be kept up by the most careful nursing. A careless or ignorant nurse can ruin all the surgeon's good work in a moment. No one can tell if an instrument has really been dropped on the floor since it was boiled; it does not show. The surgeon must be able to trust absolutely the nurses who help him.

So if Florence Nightingale, or someone like her, had not made nursing into a real profession, which clever and careful women will go into, *asepsis* could never have been used.

STORY IX

MADAME CURIE

(born 1867)

CHAPTER I

I DON'T ADVISE anybody who reads this book to try and remember very much of this chapter, except the part about Madame Curie herself. There are two reasons for this. The first is that so much is being found out about the part of science that Madame Curie and the people who worked with her began to discover, that ideas out of this book will be old-fashioned before you have properly learned them. The other reason is that the subject is really very difficult. I don't understand it myself, and am only trying to say more plainly what I have been told by people who do understand it, and what I have been able to find out from the easier sort of book

Well, when you make a really difficult subject sound as easy as I hope it is going to sound in this chapter, it means that you have not really been telling the truth about it. Supposing I, as I am

now, started telling you, as you are now, about what are called the Atomic Theory, and the Quantum Theory, and the marvellous things that have grown out of the discovery of radium.* If I did it would be like an Australian bushman trying to describe a wireless set to an African pigmy. It would all sound exciting, but I doubt if the pigmy would be able to make himself a wireless set at the end of the conversation.

We could both of us learn the facts about radium if we took a great deal of trouble and a long time. But at present neither of us has learned them.

But as long as you remember that the facts I am giving you are snippets, I think you'll be interested. This, anyhow, is the story.

Madame Curie, who was called Marie Sklodowska before she married Pierre Curie, was one of the very few women who have found out new facts about the world. There have been one or two, but very few, just as there have been very few women who have been good at painting pictures, or designing ships, or at doing any-

* The Quantum Theory is a theory about the way in which energy is given off and the way in which things move People, such as Newton and Galileo, used to think that if you rolled a ball downhill it rolled quite smoothly, but now it is thought, after even more careful watching and measuring, that it moves in jerks You will not be able to see this happening, so don't try Light flows from a lamp to your eye in little packets, heat flows out from the sun in lumps—you can no more get part of a light or a heat packet, than you could take half a dog for a walk

thing of that sort. Perhaps quite soon there will be more—perhaps some girl who is reading this book is going to be one of the people that my grand-children and great-grand-children will have to learn about.

This Marie Sklodowska was born in Warsaw, which is the capital of Poland, in 1867, when Queen Victoria reigned in England, and when Disraeli and Gladstone were two of the great men. Marie's father was the science master at one of the big colleges in the town, and her mother died young, leaving a family of small children.

Her father, Dr Sklodowski,* in his free time at home, used to do scientific experiments. He always said that it was very important not to try and learn too much science out of books, and that you ought to work with the chemicals, or germs, or electrical apparatus, or whatever it was that you were learning about. But the other people at the college where he taught, did not agree with him, and so there was no proper laboratory in the college, and Dr Sklodowski very often had to buy what he needed out of his own pocket and work at it at home. He could not afford to pay anyone to help him keep his laboratory in order, and to wash out his test-tubes and bottles.

When she was about ten, his little daughter

* 'Ski' is the masculine, 'ska' the feminine, ending in Polish names

Marie took to coming into the laboratory when he was working ; she used to wear a large apron and bring in several dusters, and she would start tidying up for him. She was very neat-fingered and didn't break things. At first he thought that she only came as a sort of game, just imitating him, and that the craze would soon be over. But she soon began to ask questions—very intelligent questions—and he found that she was really interested in what went on in the laboratory.

Directly he found this out, he began to teach her. Soon she began to go to school, but still she went on helping her father in the evening, and when she was in her 'teens she could be trusted to have all the things ready in the laboratory for the next day's work. Her father got into the habit of trying on her the lecture that he was going to deliver to the students, to see whether it was too long or too short, or too difficult or too easy. In this way Marie learned a great deal.

Marie grew up to be a very attractive girl, and she was interested in a great many things besides what went on in the laboratory. She grew up in a very sad time. England was rich and peaceful, but Poland was neither. The Russian Czar ruled over most of Poland, and the young people, students and so on, hated having a foreign Czar, so they rebelled against him. The Czar forbade them to teach the Polish language in the schools ;

they were not allowed to dance their national dances or sing their national hymns. Of course, just because it was forbidden, everybody wanted to study the language, dance Polish dances, and sing Polish songs. But these things were supposed to be signs of rebellion, and if people were caught rebelling they might be sent as prisoners to Siberia for many years.

Marie soon joined the rebels, but she and her friends were young people and could not do much against the Czar's soldiers and secret police. They used to talk Polish, and hold meetings, and draw up plans of what they would do; but before it had got further than this, the police began to suspect what was happening. It was considered best that Marie Sklodowska should leave Warsaw.

At first she thought she would go to Cracow, a Polish city in Austria, and a story is told that the secretary of the university there, on being asked to put her down as a student of physics and chemistry, told her that this sort of study was not for her, and that he would put her down for the cookery class because she was only a woman. Anyhow, she did not go to Cracow, but to Paris, where the best work in the sort of science that she had been studying was being done. She went to the great Paris university called the Sorbonne.

It wasn't long before some of the professors began to notice this intelligent Polish girl, with her

bright blue-grey eyes and her mass of fair wavy hair. The head professor told Pierre Curie, one of the young professors, that he had better look after and help this Marie Sklodowska. Soon a very nice thing happened: she and Pierre Curie fell in love and resolved to marry. But she did not leave off her work when they married—that wasn't at all their idea; in fact, part of the plan of marrying was that they should go on together at the work they both loved.

CHAPTER 2

Now at that time (1896), just about when motor-cars were invented, Pierre Curie and some of the others at the Sorbonne were working to find out some more about a queer stuff called uranium. A man named Becquerel had been specially busy about it. This uranium is something you find in pitch-blende, which is a blacky-brown, heavy mineral found in Cornwall and in Bohemia (now Czecho-Slovakia). Uranium was very odd stuff: it apparently gave out a faint, greenish-yellow glow. One day somebody tried an experiment. At the bottom of a drawer they had a photographic plate with no photograph on it, on top of it they put a medal of some kind, and on the top of that some pitch-blende. Of course,

when the drawer was shut it was perfectly dark. When they opened it, however, after some time, they found that there was an outline of the medal on the photographic plate.

The only possible source of light in the drawer was the pitch-blende. It was the uranium in the pitch-blende that gave the light. This was the first thing they discovered of this sort. The only thing at all like it had been discovered the year before. A Dr Röntgen had discovered in very much the same sort of way the rays (X-rays) given out by electric discharge tubes. Out of this discovery have grown the wonderful X-ray machines that are used by doctors. As you know, it is possible now, by means of X-rays, to take a photograph of a person's bones through his skin.

But the Curies, particularly Madame Curie, believed that there was something in the pitch-blende even more interesting than the uranium. Pierre Curie discovered that if you got uranium absolutely pure, which it was very difficult to do, it was not lively and did not give out light, like the first lot. So then they came to the conclusion that it must have been some scraps of something else mixed with the uranium that had really been doing all the queer things that they thought had been done by the uranium.

The trouble was that there seemed to be almost

impossibly little of this stuff in the amount of uranium and of pitch-blende that they had. You know, if you were only shown about a square inch of an animal, it would be very difficult to tell whether it was a cat or a rabbit, a guinea-pig or a hare. Well, so it was in this case. They came to the conclusion that the only thing was to get a great deal more of the heavy, blacky-brown pitch-blende. Madame Curie thought if she had a real mass of it there would be more chance of having enough of the unknown thing to work upon.

So she got someone to write to the Austrian Government, and they sent them from Bohemia a ton of waste pitch-blende. A whole ton of pitch-blende was a tremendous undertaking: at first they had to work with spades and pails, there was so much of the stuff. Every cupboard and store-place in the Curies' laboratory was bulging and bursting with pitch-blende. Every crumb of the stuff had to be examined, and tested and tested again. They tested it for electricity with an electroscope, they tested it with a spectroscope to see what colour it turned a flame, they tried all sorts of chemical tests with it. They began to notice that if they worked for many hours with pitch-blende their hands began to suffer: in fact, poor Pierre Curie's hands began to be quite crippled.

Well, to cut a long story short, it was found that

they had been quite right. It had been simply because they had not got the uranium out perfectly pure that it had behaved in this curious fashion, and after a great deal of work Madame Curie, with the help of Pierre, was able to isolate some odd stuff which she named Polonium.* But this polonium was nothing to the strange stuff which she managed to scrape together and refine out afterwards. It was the strangest kind of matter known to us. It was something that had never been seen in the world before. She named it Radium.

Radium looked like a whitish earth, or powdered metal, and there was very little of it even in that whole ton of browny-black pitch-blende. Like the impure uranium, it seemed to give off enough light to take photographs with if you gave it time. If you mixed a little of a stuff called zinc-blende with it, it gave off a sort of coloured phosphorescence. It was slightly warm, without being on fire. It changed certain other chemicals when it touched them. It turned the glass tubes in which it was kept mauve or pink.

As soon as she published the results of her discovery (she called it 'Thesis on Radio-Active Substances') all kinds of scientists began to get very much excited, and Madame Curie found herself a famous woman. English scientists were

* She named it after her native country, Poland

very much interested, and she came to London and was presented with the Davy Medal.*

Rutherford and Soddy were two of the English scientists who studied the new stuff.

It seemed to scientists then as though an entirely new world had been opened out. These tiny crumbs of radium taught them something about the way in which all matter was built, that they did not know before; and it had the most extraordinary consequences in science. Radium was found to be going off all the time like a kind of tiny Catherine-wheel. This was what made it warm. You could not see the sparks, but if you carried a crumb of radium about in a glass tube in your waistcoat pocket, as one of them did, you might easily get a burn right through to your ribs.

They began to argue that it must have something in common with other sorts of matter; and that if one sort of matter could behave like this, perhaps all matter might. They began to find very small traces of radium in other earths and in sea water. A new idea gradually dawned on scientists, that all matter has force in it, something like electricity.

Funnily enough, the Greeks and Romans had got hold of the idea that all matter is made up of little specks—even slime, even water. So the

* Founded to keep alive the memory of Sir Humphry Davy, who, as you perhaps remember, had been Faraday's master.

ground was prepared in a way. This idea of specks was called the Atomic Theory. But no one had any idea what the tiniest speck of all would be like. This was the very thing that the discovery of radium helped them to find out. As everything—your body, and the sun, and the cat—is made up of atoms, you can guess that all sorts of scientists got to work at once.

Astronomers were able to make very much closer guesses at why the sun goes on glowing and glowing and does not burn itself up. Later, doctors found in radium something to help them in the fight against cancer, a bad illness up till then believed incurable. Chemists made all sorts of new guesses, and experiments to see if they worked. They found that one sort of thing was often turning into other things. A bit of lead was lead now, but they could see it had once been something else, rather as a frog was once a tadpole

People then began to wonder whether other matter might not be made to behave like radium. Everything, it was already agreed, was made up out of atoms. Now they thought they knew what an atom was like. An atom, they now thought, was a curious little thing almost like a sun with its planets: in the middle of the atom was the nucleus, and electrons—tiny charges of electricity—were thought to go careering round this middle nucleus, like the planets round the sun. But in radium the nucleus

was exploding and going off—fizz! fizz!—all the time. Of course in time the fizzing would wear out the radium, but so very, very slowly that as yet no radium crumb had been noticed to get smaller.

Why, they thought, should not other atoms be made to behave like this, be made to fizz too, and gradually turn themselves into something else?

It became the desire, particularly of Rutherford, to split the atom, as it was called, or really to split the nucleus.

If only we could set free the energy that seemed almost ready to free itself in uranium atoms (and which was probably holding all other atoms together) it would surely drive ships, trains, aeroplanes, cars, warm our houses and so on. Perhaps no one would have to work in dark coal mines or live in smelly oil towns any more?

At last Rutherford did split the atom and set free a very little of this nuclear energy, but, to do it, he had to use such a lot of electricity that it almost seemed that nuclear energy was of no practical use. But the search went on, and men like Nils Bohr, Plank, Blackett, Cockroft and many others, all with teams of helpers, went on working.

Soon Nuclear-Physics became a separate science, for these tiny particles behave in a way almost the opposite of that of ordinary-sized things. Scientists who had learned the older physics and

now studied particles, felt almost as bewildered as someone who had only studied crowds might feel if he began to see into the thoughts of just one person.

Then came a new stage. Soldiers, sailors and airmen, between 1939 and 1945, were fighting the war against Hitler—and now, another secret war—a race—was going on in physics laboratories. When the Germans got Denmark the thing they wanted most was not her butter, cheese or bacon, but her great physicist, Nils Bohr

They did not get him and, as you know, the allies won the race. It was a race to make the Atom Bomb.

Why can we now release nuclear energy so much more easily than Rutherford could? The new thing that had been discovered is that there are various kinds of uranium atoms and that some kinds can be persuaded to split themselves, either exploding violently (the bomb) or more slowly to produce heat and usable energy.

Many of us have a feeling of guilt, for atom bombs were what we made and the allies dropped two of them with horrible results, on two Japanese cities—Hiroshima and Nagasaki. The race to make more bombs goes on.

To-day Nuclear-Physics labs are surrounded by high barbed wire and the workers are sworn to secrecy

The latest weapons, the H bomb and long-range rocket, are much worse than any previous

ones. Yet surely it is a good thing that so many people feel that bombs are so awful! Fighting wars was never a very good idea, and it is a fact that modern warfare is utterly horrible There surely is something specially wrong in using knowledge that could help whole nations to have the things they badly need, just for destruction Many people just think of the bomb as an instance of this, but some are also beginning to have an idea—just as the Inquisition had—that perhaps scientific knowledge is wicked? I don't believe that, but what seems a good idea is also to try to find out why nations still behave so badly and how we could learn to behave better. Luckily there are people who are trying hard to find out more about this, but it is complicated, so that Psychology and Social-Anthropology (as two of these new sciences are called) are still at the stage when no one is sure about how best to find out, and when puzzles keep cropping up that no one can make head or tail of But all that was once the trouble with the older sciences. Think of Pasteur and Leeuwenhoek for instance, and see what Harvey and Franklin said (it's on page eleven).

I wonder if M. and Madame Curie, or Bequerel, or Lord Rutherford, knew that their work would make us wonder as people had in Darwin's time, whether science is good or bad?

Pierre Curie died rather young, he was run over

in the street, but Madame Curie lived on for many years and they had two daughters who both became distinguished women.

There is a last point about Madame Curie's story that is worth noticing. Partly because of her example, it is now much easier for girls to become scientists. She proved, for one thing, that it is possible for a woman to be a good scientist and also to marry and have children. To-day if you go to almost any big meeting of scientists, you will find that about a quarter of the research workers (people who are trying to find out more) will be women. This is specially true of the new sciences that have to do with how people behave—Psychology and Social-Anthropology. If you are a girl, and want to learn something difficult, that seems to you interesting, and people tell you to go and learn cooking instead, remember Madame Curie. She happens to be the only woman discoverer in this book and still there are more men than women who do that sort of work, but enough women do it now for us to be quite sure that it is worth while for a girl to try if she wants to.

I wish there were space in this book to tell about Dr. Margaret Mead and Dr. Ruth Benedict for instance, two famous Social Anthropologists. They are two women who have proved, just as Madame Curie did, that there are women as well as men who find out

STORY X

FIGHTING YELLOW FEVER

CHAPTER I

DID YOU EVER hear the legend of the *Flying Dutchman?* The story is that the captain of a certain ship committed a crime so horrible that he could never land at a port. The wind and the tides washed him out to sea again if ever he tried. He could not even die, but was condemned for ever and ever to sail the seas.

There are true stories very like the story of the *Flying Dutchman.* In the old days, if a sailor on a ship got the dreaded yellow fever—' Yellow Jack ' they called it—that whole ship would be driven away from port after port, even if there was a bad storm. The townspeople all along the coast of the Spanish Main were terrified of Yellow Jack. Whole towns would be devastated by it. It had always been the curse of that region, and Columbus, who discovered America, lost many a brave man from his crew by this disease.

Time went on, and up till fifty years ago no cure

for Yellow Jack had been found. It was still a fearful plague all through the hot part of America.

One day a great engineer named Lesseps was looking at a map of the world. He, and the men under him, had just finished cutting the Suez Canal. Where else, he thought, as he looked at the map, was a great canal wanted? Then he put his finger upon a narrow bit of land between North and South America, on the Isthmus of Panama.

There should be another canal! He would mix the waters of the Pacific and Atlantic Oceans. He would open a new ocean gateway, and ships should be saved the terrible voyage round the Horn.

He went to the Isthmus of Panama, saw that the hills were low, and made light of the work. He asked for money, and the French people subscribed millions of francs. They felt sure that Lesseps could do the work; he had made the Suez Canal—that was quite enough proof that he could do the same at Panama. But he had forgotten one thing, although something had happened that might have warned him.

In January, 1880, the work was begun. Trouble came at once. No sooner were the first camps for the workers put up, than the dreadful yellow fever made its appearance. Every day there were new cases; six or seven strong young Frenchmen, who had gone out to Panama full of hope, would feel giddy and have no appetite. The next day they

would be in a high fever with parched yellow skins. Their heads would ache, and their eyes would be bloodshot and the light would hurt them. On the fourth day they were often dead. If they got better they were weak and ill for a long time. The older men got it just as much as the younger ones. It seemed as though death was in the air. They could not get on with the work, for the disease seemed to become stronger and kill quicker. Fresh men were sent out, but newcomers would sicken and die within a few days of their landing. At last, it was too much—the survivors left for home.

Over fifty million pounds had been wasted, and nearly twenty thousand lives lost. Railway engines, trucks, temporary bridges, temporary railway lines, machinery worth a dozen fortunes, were left scattered about haphazard. There they lay year after year. The jungle crept back again and hid everything with its greenery, parrots nested in the funnels of the engines, monkeys chattered and swung on the rusty iron cranes. Lesseps had failed.

Twelve years passed, and now the Americans were supposed to be fighting the Spaniards in Cuba. But just as the French engineers had been unable to get on with their canal, so now the American soldiers were unable to get on with their war. Yellow Jack! They had Yellow Jack in the camps. In Havana, the capital of Cuba, hundreds

of men went down with the dreadful sickness. The hospitals were full of them. The doctors and nurses worked day and night, but they did not know what caused the yellow fever, they could not cure it, and they could do nothing except help the men to die without too much pain.

Then the real fight against yellow fever began. The Surgeon-General of the American Army appointed some Army doctors, with Major Walter Reed at the head of them. There was another named Carroll, and another named Lazear. The Surgeon-General told them that they were to try and find out the cause of the disease. They began at once to experiment. They determined to find out exactly how it was caught. One of the first things that happened when they began to try and find out was that they were told a piece of gossip.

'Do you know,' somebody told them, 'there is a funny old man here, Dr Carlos Finlay. He says that you can't catch yellow fever even from someone who is dying of it, but that you get it from the bite of a mosquito—a special mosquito, a silver-striped one.'

Most people laughed at old Dr Finlay. Mosquitoes did not catch yellow fever, so how could they give it to people?

Reed determined that he would find out how people did catch it, so he gave out a notice. He

explained that so far it had been found impossible to give yellow fever to animals, and that it would be necessary to experiment on human beings, and he asked some people to come forward and allow themselves to be experimented on.

One of the first people who volunteered was Dr Carroll, and after him three or four particularly brave American soldiers came forward and said that they were ready to take the terrible risk of getting the fever for the sake of saving thousands of lives.

All this happened in the year 1900.

The first thing that Reed determined to do was to see whether yellow fever was carried in the ordinary way, as most infectious illnesses are—that is to say, whether you could catch it direct from the sick man himself, or from his clothes and bedding.

He tried this test: he shut up two healthy young soldiers in a little wooden hut. The climate of Havana was hot enough; to make it hotter still, this little hut had a stove in it. Mattresses, blankets, and sheets from the fever wards were dragged in. The two healthy young soldiers were even given the pyjamas that the sick men had worn before they died. The windows were mostly shut, and those that opened had gauze over them, so that there was no chance of Dr Finlay's mosquitoes getting in. If the two young men caught

yellow fever, it would be from the blankets and things.

It was terribly stuffy in the hut and horribly hot, and it must have been a most unpleasant test. But though they may have been rather miserable, the two young men did not get yellow fever. The doctors tried this experiment several times with different people; for some people never get yellow fever anyhow, they are what is called immune—just as some people are immune from measles and whooping-cough. So it was necessary to try several people in case the first two had happened to be immune. However, after the experiment had been repeated several times it was found that none of the young men who allowed this experiment to be made, got yellow fever.

Then Reed and his doctors made another experiment. First of all, they kept three or four healthy young men right away from anyone who had been near any of the yellow fever cases. They gave them a beautifully clean hut to live in, and the best food and fresh air. When they had been away from the yellow fever cases so long that there was no possibility that they might have picked up the illness by chance, a curious little gauze cage was brought to the hut. What do you think it contained?

It contained silver-striped mosquitoes of the kind that Dr Finlay said caused yellow fever. They

were she-mosquitoes and every one of them had recently been allowed to bite men sick with yellow fever. The mosquitoes in the cage were all hungry, and in the evening, just as the young men went to bed, the whole cageful of them was loosed in the room. In a few minutes the young men were bitten all round their eyes and wrists and faces.

Sure enough, in a few days they began to feel ill: their temperatures went up, their skins got parched and yellow, they had headaches, and their eyes were bloodshot. They had yellow fever—yellow fever which they could only have caught by being bitten by silver-striped mosquitoes. The men who slept in the little hut on the very bedding of the men who had died were none the worse, but these men, who had fresh air, clean bedding, and the best of everything, got yellow fever.

But one of the doctors, Dr Lazear, wouldn't believe. He said: 'You haven't proved it yet, Reed. We aren't sure.'

One day Lazear was going round the wards, attending men sick of yellow fever. He heard z-z-z-z. One of the silver-striped mosquitoes had settled on his hand. He could have brushed her off, but he wouldn't. He said: 'If this mosquito bites me, and then I get yellow fever, it will be a fine test.'

That was on September 13th, 1900. On the evening of September 18th, Dr Lazear began

to feel ill. Up and up went his temperature, his eyes got bloodshot, his face got yellow, and twelve days later he was dead.

One of the volunteers was a young nurse: she got yellow fever.

There would not be space here to tell about all the experiments—how sure this group of doctors made before they would declare that they had found out how yellow fever was caused; but at last, though (as you will see later) something seemed to be missing, they had really got an answer

Something was certain now. Yellow fever came from the bites of silver-striped she-mosquitoes who had bitten sick men, and it could not be got in any other way.

Reed wrote a letter to his wife: 'Rejoice with me, Sweetheart. I could shout for joy. Old Dr Finlay will be delighted beyond bounds. I thank God, Who has allowed me to look a little way into His secrets.'

Now they knew what was to be done.

CHAPTER 2

Do you know the life history of a gnat? A gnat is only a small, harmless kind of mosquito. As you probably know, gnats begin their lives in rain-water barrels or puddles. The young ones (which

are a little like tiny tadpoles) are often called wiggle-waggles. There is a most delightful description of wiggle-waggles in a book written in 1665 by a man named Hook. He was a Fellow of the Royal Society, and as you will tell by the date, he was working at much the same time as Leeuwenhoek, and he had a microscope. This is how he decribed them in the language of his day :

'This little creature you shall seldom miss all summer long. In rain-water, if it have stood any time open to the air, there will be store of them, striking to and fro. 'Tis a creature differing in shape from any I ever observed. It has a very large head all covered with a shell, and up and down the several parts of it are tufts of hairs or bristles. It has two horns like the horns of an ox inverted. Both its motion and rest are very strange and pleasant, differing from those of most other creatures I have observed.

'Having kept several of these animals in a glass of rain-water, I found after about a fortnight or three weeks' keeping, that several of them flew away in gnats, leaving their hulks behind them in the water, floating under the surface. This made me more diligent to watch them, to see if I could find them at the time of their transformation.

'Not long after, I observed several of them to be changed into an unusual shape, their head and body being grown much bigger and deeper. . . . I marked progress from time to time, and found its body still to grow bigger and bigger, nature as it were fitting and accoutring it for the lighter element

of which it was going to be an inhabitant. By observing one of these with my microscope, I found the eyes of it to be altogether differing from what they seemed before, appearing now all pearled or knobbed, like the eyes of gnats. . . .

'At length I saw a part of this creature to swim above, and part beneath, the surface of the water. After a little longer expectation I found that the head and body of a gnat began to appear and stand clear above the surface. By degrees it drew out its legges, first the two foremost, then the other. At length its whole body, perfect and entire, appeared out of the husk, which it left upon the water, standing on its legges on the top of the water. By degrees it began to move, and after flew about the glass, a perfect gnat. Because the thing is so different from the usual progress of other animals, I judge an account of it may not only be pleasant, but very useful and necessary towards a completing of natural history.' *

You can easily see that these gnat wiggle-waggles which Hook described so lovingly cannot live without water. They are distinctly water animals. The silver-striped mosquito is no different. Drain away all the water, and there will be no more wiggle-waggles. If there are no more wiggle-waggles, there will be no silver-striped she-mosquitoes. If there are no more silver-striped she-mosquitoes, there will be no more yellow fever. And, queerest consequence of all from such a dis-

* *Cambridge Readings in the Literature of Science,* by W. C. & M. Dampier Whetham.

covery—you can now have another try at digging the Panama Canal! It sounds like a cross between the House that Jack Built and a detective story, but it worked; and indeed, it is working at this moment.

Now, very much the same story had been found out about another terrible disease called malaria, which used to make whole tracts of Italy and many other countries uninhabitable. Some of the sick Frenchmen at the Panama Canal who had not got yellow fever had got malaria instead; and quite independently, far away, it had been discovered that a mosquito was also the cause of malaria—not the same kind of mosquito, but one which also grew from a wiggle-waggle. In both cases, as you will see, the cure was the same. It was to drain the marshes and ditches, or spray the water with paraffin, which kills wiggle-waggles. Not even a dish must be left standing outside a house with water in it, in any of the districts where there was malaria or yellow fever about. Clean out the drains, swill out the gutters—then there will be no more yellow fever and no more malaria in the town or in the camp.

A wonderful and cheerful work was done by the doctors and sanitary men in cleaning up the Panama Canal zone. When they had done their work, the engineers came back; and now the Panama Canal is one of the wonders of the world,

and ships no longer have to make the dreadful passage round Cape Horn.

CHAPTER 3

But that is not the end of the story. It is true that there is no yellow fever in civilized places now; but it is still impossible to drain the great jungles of the Amazon, or those Brazilian forests which Darwin described. Nor is it possible to spray the whole of West Africa with paraffin. In such wild and savage places, yellow fever still has its home.

Now, a Japanese doctor, Hideyo Noguchi, had for a long time been studying the human blood under all sorts of queer conditions. He studied the blood of people who had been bitten by snakes; he studied the ways of a kind of wriggling microbe called a spirochæte, a number of varieties of which he grew for the first time in test-tubes in his laboratory.

In the year 1918, just after the First World War was finished, Noguchi observed in the blood of a person sick of yellow fever, a very delicate, very tiny, corkscrew creature, very like the spirochætes which he had been studying before. He went off to Guayaquil in Ecuador, on the west coast of South America, where there were plenty

of people sick of yellow fever, to see whether he could find more of his wriggling corkscrews.

For as you can imagine, a great many doctors and microbe-hunters had been cutting up silver-striped mosquitoes to look for the germ The difficulty always was that silver-striped mosquitoes seemed to have a great many different germs inside them.

For instance, a doctor named Adrian Stokes had gone off to West Africa, to a place called Accra, to try and find the germ, just about the same time that Noguchi went to Ecuador. Dr Adrian Stokes did not think that Noguchi's wriggling corkscrew was the one to cause yellow fever at all. He thought it was something very much tinier. He had found the tiniest of all living creatures in the insides of the mosquitoes he had cut up—a virus.

I have not, up till now, explained why it was that they wanted to find the germ, because, if you have read the chapter on Pasteur, I suppose that you will already have guessed. What they wanted to do was to make sure which germ it was · then, when they had made sure, to grow it in their laboratories, weaken it, and then inoculate people with doses of it, so that they could not get yellow fever. This business is called making a vaccine.

But there was one great difficulty about making a vaccine for yellow fever. You need not only test-tubes to grow the germs in, but animals to try the

germs on. But it was very difficult to get any animal to catch yellow fever. Noguchi found it was possible to give it to guinea-pigs, but the vaccine made from the blood of guinea-pigs turned out not to be exactly the right kind to protect human beings.

But one day Dr Adrian Stokes, working in his very hot, steamy laboratory in West Africa, had a brilliant idea. Everyone knew that it was always the newcomers to a place who got Yellow Jack worst; everyone also knew that nobody ever gets Yellow Jack twice, any more than they get mumps twice, or than most people get measles twice. Stokes thought to himself: 'We can't give yellow fever to African monkeys, because they are not newcomers—they are too used to the germs. But if we could get monkeys from somewhere else, where nobody ever has yellow fever, then perhaps we could give it to them and make a vaccine from their blood.'*

Stokes got over from India several apes and monkeys, and found, as he had hoped, that they would get yellow fever when the silver-striped she-mosquitoes bit them. But he was still no nearer

* By the way, animals that are given diseases in the course of making vaccines very often get better. A friend of mine once had two very friendly piebald rats as pets They had been used for this, and had got better more than once So they had been pensioned off and allowed to live in comfort for the rest of their lives They were so tame and well-behaved that they did not have to be kept in a cage

finding out which of the germs that live so happily in the insides of silver-striped mosquitoes was the one that caused the illness.

Noguchi, working in South America, heard all about what Adrian Stokes was doing, and was very much interested. He felt sure that the germ he had found was really the one—the corkscrew, wriggly one. If only, thought Noguchi, this fellow was properly grown and prepared, he would give yellow fever to Indian monkeys, just as well as a bite from a real mosquito would give it.

Just then poor Dr Adrian Stokes got yellow fever and died Noguchi thought that his work ought to be gone on with. There was a great deal to be found out. For instance, it was possible that South American Yellow Jack and African Yellow Jack were two separate diseases. So the Japanese doctor took the long journey to West Africa, although he knew that the dreadful Yellow Jack had just killed Dr Adrian Stokes, and that he himself was not well and might easily be killed too. And so it proved.

Noguchi was fifty-two when he went to Accra, and a great many of his fellow workers did not want him to risk his life. They knew that even the most experienced and careful workers cannot do experiments in places where there is a great deal of yellow fever about, without running the gravest risks. They knew that Dr Adrian Stokes had been as

careful as he could, not to get bitten by infected mosquitoes ; but it had happened, and he had died, and it was quite likely that this very thing would happen to Noguchi, who was older and therefore more likely to get it. However, Noguchi took no notice, and went.

He worked at cutting up mosquitoes, he examined the blood of people sick of yellow fever, he transferred yellow fever infection from one guinea-pig to another. This was in the May of the year 1928. He had just finished his experiments, and had all the information about them shut up in his notebooks, and was ready to sail home. He was to have gone on May 19th. But on May 15th he began to feel ill, and by May 21st, two days after he ought to have been safe on board, he was dead.

Dr Sellards was the next to go on with the war ; but he thought that it was foolish to go on working at a place like Accra, where there were so many mosquitoes and so much yellow fever about, that, be as careful as you might, you could not be sure of not being bitten by an infected mosquito. He was of opinion that Dr Stokes was right—not Dr Noguchi : that is to say, he thought that it was the virus in the inside of the silver-striped mosquito that gave people yellow fever, and not the corkscrew germ.

Now viruses are very queer things. They are

the simplest of living things that we know about, the nearest to not being alive at all—things much less alive than a fungus or a lichen or a yeast. Most very simple things can stand a great deal of knocking about, and a virus can stand being put into cold storage for weeks and weeks, and can be revived again at the end of its journey.

So instead of staying in Africa, Dr Sellards decided that it would be much more sensible to take the virus back to a really good laboratory somewhere in America, where it could be studied without any risk of his being bitten by infected mosquitoes.

He worked in Boston as a rule, and was on his way to America with a supply of frozen virus, but he stopped in London to hear the news and look about him. Some interesting work was being done in London—for instance, by Dr Laidlaw and Mr Dunkin. Distemper in dogs is also caused by a virus, and Dr Laidlaw had just made a vaccine which will prevent dogs' distemper.*

I suppose all the doctors got talking about this and that. Anyhow, the end of it was that Dr Sellards, who had brought the yellow fever virus back from West Africa, gave some of it as a present to another doctor called Hindle.

* If you have a puppy that you are very fond of, a vet can give it a dose of the vaccine, when it is a few months old, and it will almost certainly not die of distemper, as so many puppies used to do

And now comes the putting together of this strange jig-saw puzzle. Dr Hindle had read all about Adrian Stokes's discovery—the discovery that yellow fever can be given to Indian monkeys, though not to African monkeys. Dr Hindle had also studied all the work that had been done on dogs' distemper; and finally, in the autumn of that year, he made a vaccine.

This vaccine has proved to be a success. Protective doses of it are given and the person who has had them will not get yellow fever. This vaccine was only perfected just in time and the reason it was so urgent is interesting and curious.

You know that aeroplanes now fly regularly to Asia from Africa and South America, and that such air journeys don't take as many days, as a journey by sea does weeks This means that a person who had been in a place where there is yellow fever, though quite well when he started might now sicken with yellow fever a few days later in Asia. There are plenty of those silver striped she-mosquitoes in Asia, but, up to now, not one of them has ever bitten a person with yellow fever, so that at present their bite is harmless. But if once someone with yellow fever on them landed in Asia, they would quite likely be bitten by one of these 'carrier' mosquitoes, and then, the most likely thing in the world would be that this same mosquito would go on and bite

somebody else and so on. If you remember one of the points about yellow fever is that it is always newcomers who get the disease the worst. So, as it has never been known in Asia, doctors think that once it got in it might rage all over India and China and all the other Asian countries and kill people not in thousands but in millions.

That is why, to-day, each person who comes in an aeroplane from any yellow fever district of Africa or South America must have a certificate, signed and stamped by a doctor, to say that they really have had proper doses of the vaccine that protects against yellow fever. If they haven't got a certificate they are shut away for about a week in a special hospital ward with wire gauze over the windows and doors to prevent mosquitoes getting in. As a further precaution, the moment it lands, while the aeroplane is still on the runway, and before the passengers are allowed to get out, each 'plane is sprayed with a strong insect-killing spray, which smells very nasty.

I landed in Asia once in an aeroplane in which one of the other passengers had come from Africa and hadn't got a proper certificate of vaccination, though he was perfectly well, sure enough, he was taken off in an ambulance and shut up, just in case.

Some of the other passengers were very much surprised and thought this was very hard on him and grumbled because all these precautions were a

great bother. But if they had known what you know, I think they would have agreed that it was quite right, because not thousands but millions of lives were at stake

CONCLUSION

I DO HOPE you have enjoyed reading about these people—Galileo, Darwin, Madame Curie, and so on. I wonder if you will agree with me, now that the book is finished, that soldiers and sailors, and Prime Ministers and Kings, are not the only ones who do great deeds and who ought to be famous in history?

If I had to tell a person from another planet what special things Man can do, I don't believe I should tell him about the deeds of the usual history-book people at all, hardly even about Cæsar or Napoleon, and certainly not about Hannibal, or Drake, or Sir Robert Walpole. Other creatures do that sort of thing so well: lions are brave and bold, swallows can travel far and fast, and a bull or a bell-wether is often a wise and cunning leader. But only Man finds things out. Only Man sets out on adventures. Only Man has to be bold in guessing, patient in testing, truthful in saying what he knows, and self-sacrificing in not selling his knowledge for money.

The discoverers who are described in this book, and many more like them, are the people I should

choose to show someone from another planet. Such adventurers do what Man, and only Man, can do of all the creatures on the earth.

I say 'many more like them,' because there are plenty more stories to tell. It was quite hard to pick out a bookful, just because there are so many. For instance, there was Malpighi, who was just as interesting as Leeuwenhoek. Then the story of the great astronomer, Herschel, is exceedingly interesting. He mapped out the whole sky, and patiently looked at every little bit of it through his telescope. His sister helped him, the work took years, and he found out amazing things. It was hard to know whether to tell the story of Faraday or Franklin: Franklin's is such an amusing story, because besides being a discoverer who found out a great deal about electricity, he was also a sort of ambassador from America to Europe, just when America first became independent, and he was always having to fit in his scientific discoveries with his work for the new growing country.

Then Tycho Brahe, who came just before Galileo, a strange old gentleman in Denmark, in a long furred robe and a beard, had a most exciting story. To begin with he was a roystering young nobleman, and probably would never have bothered much about astronomy if he hadn't had his nose cut off in a duel. He made himself a false nose and became a learned man. The King of

Denmark got very much interested in his astronomy and helped him to build a great castle called Uranianburg, which was half observatory and half palace. Here Tycho Brahe lived in great state, and had enormous instruments for measuring the paths of the stars. But in the end he was disgraced.

Newton was another man who made most important discoveries. Then in this book there is not a word about people who have made discoveries in two of the most exciting of the new sciences, anthropology and psychology. Anthropology means the study of the habits of man, particularly of strange tribes, and psychology means the study of the minds and memories of animals, children, and grown-up people.

There was an Englishman named Sir James Frazer who made some quite thrilling discoveries about the magic rites of people all over the world. A Russian professor named Pavlov has done some wonderful experiments on what you can teach dogs and how their minds work. Then three people, Freud, Jung, and Adler, between them could tell you a great deal about why you make spelling mistakes, why some people are frightened of the dark, and why soldiers got 'shell-shocked' in the war.

Again, I was only able to choose one, out of all the stories that there are, about fighting some particular infectious disease. Instead of putting in

the story of the fight against yellow fever, I might have put in just as good a story about the fight against malaria, or plague, or sleeping sickness. Then the story of the discovery of some stuff called insulin is very curious. But, of course, there would not be room in one book for all this.

The fact is, it is difficult for anyone to imagine how much there is left out of this book. I do hope that no one who reads it will think for a moment that (even where there seems a good deal about one particular subject, say, about the origin of species) I have put in anything like all there is to know about it. As I said before (in the beginning of the first chapter about Madame Curie), when somebody makes really difficult subjects sound as easy as I hope they do in this book, it simply means that they are not telling the whole truth about them.

In this book the truth is altered either (1) to make it sound more certain and less complicated than it really is, or (2) because I have mostly just followed what other people have written in other books. Now this is not quite a safe thing to do. If you really go to the town where a famous man lived, if you talk to people who knew him, you will almost always find that one or two mistakes have been made in the books you had read beforehand. What I have done is to read several books about each person, and if they told a particular thing differently, to choose what seemed the best account,

or else I asked someone who knew a great deal about the subject what they thought about it.

Again, though I have taken a good deal of trouble about it, there are probably a few mistakes in the science part. The fact is, no one person *could* know all there is to know about the dozen or so different discoverers who come into this book; for they all have absolutely separate departments of science. However, for all that, this book has probably not got more things wrong in it than most books.

I put all this in because, first of all, I want to explain a thing that lots of people never do get into their heads. It is this: *It is very hard to be sure about the facts of any person's life.* I once wrote a long book all about one man (John Ruskin), and took a lot of time and pains, and talked to lots of people who had known him, and still I found it hard to get at the truth.

Secondly, I put this in because *I want you to believe that when you have read this book, you have not had much about any of the sciences*—only a sniff, and a lick at the cork out of the bottle. You have just got a sort of idea of whether you would like to have a real drink or not.

The only things this book might give you a fairly clear idea about, are these three: (1) What sort of person starts on this business of finding out, (2) How they set about it, and (3) Whether this is

an interesting sort of thing to do with your life or not. Apart from that, the 'Lives' in this book are simply stories, told as truly as I could without learning to read (say) Dutch, or Italian, or to be (say) an electrician or a doctor. I hope that you may have enjoyed them.

By the way, I do hope you have read, or will read, the odd remarks made by various discoverers, which I have put at the beginning, on page 11.

THE END

CHRONOLOGICAL TABLES—I

(Some of these dates are only round about right)

	ITALY *Galileo*	ENGLAND *Harvey*	HOLLAND *Leeuwenhoek*
1564	Galileo born		
1578	Aged 14	Harvey born	
1613	Says earth goes round sun	Aged 35	
1615	Galileo aged 51	Discovers the circulation of the blood	
1616	Inquisition says he tells lies	Harvey aged 38	
1632	The Pope is angry	Aged 54	Leeuwenhoek born
1642	Galileo dies, aged 78	Watches the Battle of Edge-hill	Aged 10
1657		Harvey dies, aged 79	Aged 25
1658			Looks through his first lens
1675			Sees microbes in rain-water
1680			Rewarded by the Royal Society
1723			Leeuwenhoek dies, aged 91

(continued overleaf)

ENGLAND

	Faraday	*Darwin*	*Lister*
1791	Faraday born		
1809	Aged 18	Darwin born	
1816	Helps Davy make the miners' safety lamp	Aged 7	
1822	Faraday aged 31	Aged 13	
1827	Aged 36	Aged 18	Lister born
1831	Gives up profession to study electricity	The 'Beagle' sets out	Aged 4
1859	Faraday aged 68	*Origin of Species*	Aged 32
1865	Aged 74	Darwin aged 56	Lister begins his great work
1867	Faraday dies, aged 76	Aged 58	Lister aged 40
1877		Aged 68	Aged 50
1882		Darwin dies, aged 73	Aged 55
1885			Aged 58
1889			
1892			Lister at the Sorbonne
1895			Aged 68
1896			
1898			
1900			Aged 73
1912			Lister dies, aged 85
1918			
1926			
1928			

	France & Poland		North & South America, Japan & Africa
	Pasteur	*Madame Curie*	*Yellow Fever*
1791			
1809			
1816			
1822	Pasteur born		
1827	Aged 5		
1831	Aged 9		
1859	Aged 37		
1865	Aged 43		
1867	Aged 45	Marie Sklodowska born	
1877	Anthrax	Aged 10	
1882	Swine fever	Aged 15	
1885	Rabies	Aged 18	
1889	Pasteur aged 67	Goes to Paris	Panama Canal abandoned
1892	The Sorbonne	Aged 25	
1895	Pasteur dies, aged 73	Marries Dr Curie	
1896		Uranium	
1898		Radium	
1900		Mme Curie aged 33	Yellow Fever in Cuba Experiments begin
1912		Aged 45	
1918		Aged 51	Noguchi experiments
1926		Aged 59	Death of Dr Adrian Stokes
1928		Aged 61	Death of Noguchi Preparation of vaccine by Dr Hindle